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ABSTRACT

This action research study developed a framework for moving teachers toward an inquiry-based approach to teaching science, emphasizing elements, strategies, and supports necessary to encourage and sustain teachers' use of inquiry-based science instruction. The study involved a literature review, participant observation, focus group discussions, and anecdotal records from professional development training sessions. Participants were mathematics/science resource teachers who collaborated with teachers and supported them in implementing the inquiry-based curriculum. Researchers developed a compilation of indicators specifying inquiry-based teaching and learning from the literature review and observations. The inventory helped guide teachers toward understanding and utilizing inquiry-based science instruction. It was also a reference/study guide for teachers and staff developers. Data from the observations underscored several important considerations for moving teachers toward inquiry-based teaching. Teachers and leaders must become mentors and facilitators of learning, thus helping students construct their own knowledge and understanding. If educators use this approach in their classrooms and training, they must clearly understand the concept of inquiry-based teaching and learning, develop skills for effective inquiry-based instruction, and teach/model accordingly. A framework developed from the study includes components for encouraging and sustaining teachers' use of inquiry-based teaching (curriculum, instruction, and assessment; professional development; collaboration; professional discourse; networking; lead teacher support; administrative support; and learning community). (Contains 33 references.) (SM)

ACTION RESEARCH STUDY

A Framework to Help Move Teachers Toward an Inquiry-based Science Teaching Approach

Mary E. Staten

A Framework to Help Move Teachers Toward an Inquiry-based Science Teaching Approach

Abstract

The purpose of this action research study is to develop a framework to help move teachers toward an inquiry-based approach to teaching science. The research focuses on the elements, strategies and supports necessary for encouraging and sustaining teachers' use of inquiry-based instruction in science.

This study is a qualitative analysis which uses participant observation, an interview survey for focus group discussions, and anecdotal records from professional development training sessions as data sources. Mathematics/Science Resource Teachers (MSRT), employed by Milwaukee Public Schools (MPS), and whose role it is to collaborate with teachers for the purpose of supporting them in the implementation of the MPS inquiry-based science curriculum, served as volunteer participants in the study.

A compilation of indicators specifying inquiry-based science teaching and learning was developed from the literature review and the observations. This inventory is intended to serve as a guide to help teachers better understand and utilize inquiry-based science instruction. It is also intended for use as a reference/study guide for teachers and staff developers conducting professional development workshops and inservices using this constructivist teaching approach.

The data obtained during the observations underscore several important considerations for moving teachers toward an inquiry-based approach to teaching science. Teachers and teacher leaders need to serve more as mentors and facilitators of learning in order to help students construct their own knowledge and understanding. If MSRTs and teachers are to use this approach in their classrooms and training sessions, they will need to clearly understand the concept of inquiry-based teaching and learning, develop the skills needed for effective inquiry-based instruction, and teach/model, accordingly.

The framework was developed from the literature review, focus group discussions, and professional development training sessions. The components for encouraging and sustaining teachers' use of an inquiry-based science teaching approach include:

1.) Inquiry-based curriculum, instruction, assessment
2.) Professional development
3.) Collaboration
4.) Professional discourse
5.) Networking
6.) Lead teacher support
7.) Administrative support
8.) Learning Communities

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A Framework to Help Move Teachers Toward an Inquiry-based Science Teaching Approach

"What we want for out students, we must give to our teachers first."
Marilyn Zaretsky
(WCER Highlights 1997-98)

Introduction

The purpose of this research study is to develop a framework to help move teachers toward an inquiry-based approach to teaching science. The research focuses on the elements, strategies and supports necessary for encouraging and sustaining teachers' use of inquiry-based instruction in science.

The inquiry learning process is a key part of the *Milwaukee Public Schools (MPS) Learning Framework.* MPS asserts its commitment to an inquiry approach to teaching and learning in that educators within the MPS system "strive to have students solve problems, pose and answer sophisticated questions and engage in complex, real-life projects as a means of learning high content and skills identified in clearly stated standards" (MPS Program Effectiveness Review, Milwaukee Urban Systemic Initiative, 1997, p. 1).

Additionally, the Milwaukee Urban Systemic Initiative in Mathematics and Science (MUSI), supports the use of inquiry-based science and mathematics curriculum, instruction, and assessment. In 1996, the Milwaukee Public School System in collaboration with the National Science Foundation (NSF) began an initiative to improve the mathematics and science achievement of all MPS students. The national effort began in 1993, when the NSF announced its plans to support mathematics and science improvement in the 25 U.S. cities that had the greatest number of children living in poverty. Milwaukee is one of these cities. To accomplish this, the NSF created the Urban Systemic Initiatives (USI). The purpose of the

Milwaukee Urban Systemic Initiative (MUSI), a potential 5-year, $15 million project, is to increase both the opportunities and the achievements of all MPS students in science and mathematics and eliminate gaps in achievement along ethnic, gender, or socioeconomic lines by implementing and supporting the use of content-rich, inquiry-based science and mathematics curriculum, instruction, and assessment (Milwaukee Urban Systemic Initiative, 1996).

Integral to the design of MUSI is a cadre of Mathematics/Science Resource Teachers (MSRTs). The MSRT's primary function is to support effective teaching and learning in MPS schools through the implementation of content-rich, inquiry-based science and mathematics curriculum, instruction, and assessment. This is accomplished through ongoing collaboration with teachers, administrators, parents and the larger school communities. Collaborative techniques specific to teachers include dialogue, modeling, team teaching, and peer coaching/mentoring. In these roles, MSRTs need to clearly understand and be proficient in using inquiry-based instruction. This action research study aims to provide a framework for facilitating teachers' movement toward a more inquiry-based approach to teaching science, as well as assist MSRTs to better understand and apply inquiry-based science instruction to improve their own practice and role as agents of science pedagogy and curriculum reform.

Context

I am a high school science teacher, having taught physical science and biology to ninth and tenth grade students for three years. Since August, 1997, I have been working as a Mathematics/Science Resource Teacher (MSRT) for Milwaukee Public School System through the Milwaukee Urban Systemic Initiative (MUSI), a systemic reform effort designed to improve the mathematics and science achievement of all

MPS students. My principal function, in this leadership role, is to provide content-rich, inquiry-based science and mathematics curriculum, instruction, and assessment to teachers in my assigned schools and to support them as they begin to implement changes in their classrooms, as well as contend with the issues surrounding these changes. One of the issues arising from this reform effort, which is also the premise of this research study, is how to identify, implement, assess, and sustain effective inquiry-based teaching. It is hoped that through this action research study classroom teachers will consider the framework to construct a better understanding of teaching and learning through this process and MSRTs will utilize it to encourage and facilitate teachers, as well as their own, movement toward a more inquiry-based approach to teaching science.

According to the conclusions of the the Second and Third International Mathematics and Science Studies (TIMMS), science curriculum, as traditionally conceived and implemented in the United States, is responsible in large part for the low performance of America's students in science (U. S. Department of Education, 1998). In February 1998, the U.S. Education Department released the results of the TIMMS, which compared the performance in science (and mathematics) of 500,000 students (33,000 American) internationally at grades four, eight and twelve. The study revealed that at the fourth grade, U.S. students were near the first in the world in science. By the eighth grade, U.S. performance had fallen to slightly above the international average in science and by the twelfth grade, U.S. ranking fell to below average in science, even among those U.S. students taking advanced level science courses. Richard Riley, the U.S. Secretary of Education, recommended offering students a more challenging science curriculum and improving the teaching of science through teacher training and reduction in the large number of teachers teaching out-of-field as two of the six steps that states and communities can take to improve students' achievement in science (U. S. Department of Education,1998 & The National School Alliances, 1998).

In Milwaukee the results are just as disturbing. Milwaukee Public Schools (MPS) uses the Wisconsin Student Assessment System (WSAS) *Knowledge and Concepts Examinations* and the MPS Science Performance Assessment to measure its students' achievement and proficiency in the discipline of science. The WSAS is administered to students in grades four, eight and ten. It includes multiple-choice and short answer questions in the content areas of science, mathematics, language, and social studies. The following table shows percentile ranks of MPS students compared to the MPS Board/National goal, over a three year period, for the science component of the WSAS for grades four, eight and ten. A change in the 1996-97 tests prevent comparisons to previous years (MPS 1996-97 Accountability Report, 1997).

Table 1. WSAS Results for Science

	94-95	95-96	96-97
MPS Board/National	50	50	50
4th Grade	n/a	n/a	32*
8th Grade	39	31	27
10th Grade	41	33	33

*1996-97 First year for WSAS Administration at Grade 4

These data for Milwaukee Public Schools, the state's largest school district and the district with the highest incidence of students on free or reduced price lunch (an indicator of the poverty level), revealed disturbing trends. MPS students scored significantly below average in science. The average scores fell around the 36 percentile compared to the national percentile of 50. Significant gaps in achievement level were also seen across ethnic groups.

Table 2 shows the 1997-98 WSAS results for science (Wisconsin Department of Public Instruction, 1998). Beginning in January 1998, student scores on the WSAS were reported in proficiency levels (percentage): minimal, basic, proficient, advanced. These data indicate scores for the nationwide sample and MPS grades four, eight and ten. Only 17 % (an average of each grade level) of MPS students were considered proficient in science according to this indicator of performance. Again, major gaps in proficiency levels were seen across ethnic groups.

Table 2. WSAS Results for Science, 1997-98

	Minimal	Basic	Proficient	Advanced
National	38	30	28	6
4th Grade	38	35	25	3
8th Grade	41	42	14	3
10th Grade	59	27	12	2

Additionally, the MPS Science Performance Assessment, introduced in the 1996-1997 school year for grades five, seven and ten, is used as an indicator of student performance. This assessment strategy was developed to help identify the teaching and learning needs of students required to improve their performance in science. It consists of three to five performance tasks to assess what students know and are able to do in science. MPS district statistics for the Science Performance Assessment for 1996-97 (scores ranging from 0 - 16 points) revealed that 15.3% of students scored between 0-5 points, 34.3% between 6-11, 24.6% between 12-15, and 25.8% at 16 points or more, with an average score of 11.2 points. Sixteen points is considered proficient. The 1997-98 results were not available as of this writing.

These data highlight a critical problem in Milwaukee Public Schools and the U.S. in terms of science achievement. MPS is keenly aware of this major problem facing its schools. To help address this need MPS created an additional arm of the system, MUSI, and through the Curriculum and Instruction Division has developed curriculum and assessment designs that are content-rich and inquiry-based in nature; both for the purpose of improving student performance in science.

Literature Review

Inquiry-based Science Teaching and Learning

> Scientific inquiry is more complex than popular conceptions would have it. It is, for instance, a more subtle and demanding process than the naive idea of "making a great many careful observations and then organizing them." It is far more flexible than the rigid sequence of steps commonly depicted in textbooks as "the scientific method." It is more than just "doing experiments," and it is not confined to laboratories."
>
> Benchmarks to Science Literary (1995)

Inquiry-based science, according to the National Research Council (NRC), is a step beyond science as a process in which students learn scientific thinking skills. The NRC defines science inquiry as the "processes of science," which require that students combine processes and scientific knowledge as they use scientific reasoning and critical thinking to develop their understanding of science (National Science Education Standards, 1996). The NRC (National Science Education Standards, 1996, p. 105) asserts that engaging students in inquiry helps them to develop:

- Understanding of scientific concepts.
- An appreciation of "how we know" what we know in science.
- Understanding of the nature of science.
- Skills necessary to become independent inquirers about the natural world.
- The dispositions to use the skill, abilities, and attitudes associated with science.

The NRC believes that students in all grade levels and every field of science should have the opportunity to use scientific inquiry and develop the ability to think and demonstrate the behaviors and skills related to inquiry. These include asking questions, planning and conducting investigations, using appropriate tools and techniques to gather data, thinking critically and logically about relationships between evidence and explanations, constructing and analyzing alternative explanations, and communicating scientific arguments (National Science Standards, 1996).

Wisconsin's Model of Academic Standards (1998) also include science inquiry as a content standard for teaching and learning science. The Wisconsin model follows the format and content of the National Science Education Standards. Science inquiry, according to this model, calls upon students in Wisconsin to "investigate questions using scientific methods and tools, revise their personal understanding to accommodate knowledge, and communicate these understandings to others" (p. 61). Inquiry includes questioning, forming hypotheses, collecting and analyzing data, reaching conclusions and evaluating results, and communicating procedures and findings to others.

With respect to the classroom, Chiappetta (1997) says that upon entering an inquiry-based classroom, "one should be able to observe an exciting learning environment in which students should be asking questions, resolving discrepancies, figuring out patterns, representing ideas, discussing information, and solving problems" (p. 22). He explains two approaches to inquiry, one in which science is taught *by* inquiry and the other in which science is taught *as* inquiry. Science *by* inquiry is finding out about anything and everything. It does not specify the context or place restrictions on the approach--it is an open approach to teaching and learning. With this approach, students' attitudes, critical thinking skills, and habits of mind are also emphasized. Science *by* inquiry can also be thought of as "science through inquiry" and "learning by discovery." Teaching science *as* inquiry stresses active student learning and the importance of understanding a scientific concept. With this approach the content becomes a critical aspect of the inquiry.

Moscovici and Nelson (1998) liken Chiappetta's explanations of both approaches to inquiry-based science to what they call, "activitymania" versus inquiry. Activitymania (science by inquiry, doing science activities) is an approach to teaching science that involves "a collection of pre-packaged/recipe-type, hour-long or less, hands-on activities that are often disconnected. Each activity has a definite beginning, middle, and end. In contrast to this approach, inquiry (science as inquiry, doing science) is the process of searching for patterns and relationships in the world around us" (p. 14). With this approach, learning takes different directions according to students' interests and questions related to the concept being studied. Several characteristics of an inquiry-based science classroom are described by Moscovici and Nelson and were used to begin development of the *Inventory of Indicators to Support Inquiry-based Science Teaching* (see Appendix A). This inventory was used to observe classrooms and workshops included in this study. Data from the observations were used to expand the inventory of indicators and to design a framework for moving teachers toward an inquiry-based approach to teaching science.

Another perspective of inquiry-based science teaching comes from the *Modeling in Mathematics and Science (MIMS)* project of the National Center for Improving Student Learning & Achievement in Mathematics and Science (Principled Practice in Mathematics & Science Education, 1998). Researchers at the Center believe that the curriculum "matters." Studies conducted through the Center suggest that:

> The curricular tasks should be worth understanding in the first place: mathematics and science should be interesting, and there must be some reason for the given content's inclusion in the curricula. Such reasons include the idea's social worth (a useful idea that can be applied to solve a social or scientific problem), disciplinary worth) an idea or a method of doing science and/or mathematics that has central importance in the history of the discipline), or inherent interest (an idea that provokes student interest) .

The researchers believe that students develop deep understanding of scientific and mathematical concepts when "they engage in a challenging curriculum--and when teachers play an important role in creating and implementing such a curriculum" (p.15). The project, itself, offers a new perspective for "purposeful inquiry" in that "teachers plan, evaluate, build, and continuously reshape exactly what is studied and how, with specific attention to student thinking and development of deep understanding" (p. 2). In this perspective of teaching, important central concepts of science and mathematics are the focus of study over extended periods of time. The framework they use is called the "web of inquiry." This web of inquiry in science (or any domain) involves students in making complex connections to previous knowledge and extending those connections in ways that build new knowledge. Webs of inquiry start with questions that are identified by the teacher or result from students' curiosity as they experience the process of inquiry. Content is central to this approach, it is "not left to chance... but is driven by inquiry guided by the teachers' knowledge of the science and mathematics to be taught." (p.2).

In web of inquiry science classrooms, students participate in scientific inquiry. Guided by teachers' questions, students move from wondering about science to doing science. Student actions include formulating precise questions and conjectures, designing ways to test the conjectures, making careful observations, gathering data, representing and explaining the data, drawing conclusions based on their data, and formulating new questions and hypotheses based on what they have learned. The designers of this approach contend that learning and using science, from this perspective, results in increased student interest, ownership of their work, and deeper understanding of content.

MPS' reform strategy for science education explains that mastering challenging content through inquiry learning requires creating an environment that motivates, inspires, and encourages the intellectual risk-taking necessary to learn (MPS/MUSI Program Effectiveness Review, 1997). MPS describes an inquiry-based education as standards-based and involving both students and adults. In the classroom, students' thinking focuses on core science principles. Students use hands-on investigation to explore, discover, and learn scientific concepts and relationships in contexts that involve real-world problems. The hope is that students in this kind of learning environment gain an understanding of the scientific knowledge and concepts that enable them to pursue the continued study of science.

MPS' elementary science program, through *Explorations in Science*, was developed to include the process of inquiry as a key element of the tasks and projects offered in the program (Campbell et al., 1992). In this process, students are involved in open-ended exploration of ideas and materials, the use of a problem-solving model, formal investigations where students conduct experimentations by controlling variables and reaching conclusions, and further research. This curriculum encourages students to explore a variety of approaches and possible answers, and it facilitates the process of inquiry by providing them with opportunities to present their discoveries, pose questions, express their thinking, and hear how other students have approached similar and different problems. MPS middle school and high school science curricula have, more recently, moved toward an inquiry-based instructional approach.

But, even with national and state entities pushing science inquiry as a standard for teaching and learning science, the school district's commitment to an inquiry learning process, and content-rich, inquiry-based science curriculum programs in place in the schools, many teachers in MPS are not teaching science using this instructional approach. So, the question remains, "How do we encourage and sustain teachers' use of a more inquiry-based science teaching approach?"

As early as the 1960s, the inquiry approach to teaching science was being promoted by science educators. The National Science Foundation was instrumental in promoting this instructional approach by supporting inservice training institutes for teachers. These institutes were effective in encouraging inquiry teaching, but were eventually discontinued (Rakow, 1986).

Rakow (1986) cites a 1981 study by Welch et al. that questioned, "What do teachers perceive to be the limitations of teaching science as a process of inquiry?"

The study focused on the status of the inquiry approach in teaching science. The researchers found that teachers were not using or were increasingly giving up the approach and returning to a text-book centered approach to teaching science. The teachers identified lack of training, lack of time, lack of materials and lack of time to assemble and set up the materials (the advent of science kits--MPS established a science kit distribution center in 1995 for use by elementary teachers), lack of support from building/school or central district, over-emphasis on assessing content learning rather than process learning, and difficulty of the inquiry approach as reasons for giving up this instructional strategy. These same concerns have been echoed by science teachers, today.

Ahlgren (1990), author of *Science for All Americans* and a scientist with Project 2061, and many other scientists and educators acknowledge that shifting to the inquiry-based analytical approach (or any major curriculum change) is problematic (Rutherford and Ahlgren, 1990; Arambula-Greenfield, 1996, Kober, 1993). But, however difficult an inquiry-based system might be to implement, Ahlgren, quoted in an article by Hardy (1998) says it is the only teaching strategy that gives students a chance to explore the processes of science. Ahlgren maintains that the only way he would know if students doing a "hands-on" project were learning anything would be to interview them. He further notes that, "Under the banner of inquiry, a lot of teachers do a lot of traditional things" (p. 28).

Problem-based Learning

What alternatives may be brought to bear to address the question? Problem-based learning offers an alternative model for moving teachers toward the use of a nonconventional instructional approach through professional development. It parallels inquiry-based learning as another instructional practice for helping students develop new understandings. Problem-based learning is an instructional format requiring students to participate actively in their own learning by researching and working through a series of real-life problems to arrive at the "best" solution for that problem. The research the students pursue is supposed to help them construct the knowledge and understandings they need to address the problem or question Arambula-Greenfield,1996).

In a problem-based learning classroom teachers diagnose what and how much students understand and how they are thinking about a concept, understanding deeply the subject matter, the processes of the discipline, and its connections with other areas of knowledge and managing and conducting activities with groups of students. The problem-based teaching approach is said to be a powerful strategy for motivating students, for developing skills in critical thinking and problem solving and for deepening students' understanding of significant content. It is used to encourage students to explore information in multiple ways and to learn about authentic problems (Sage & Thorp, 1997).

Arambula-Greenfield (1996, p. 26) outlines the characteristics of the "pure" approaches to problem-based learning in her article discussing her redesign of a college science course for undergraduate nonscience majors. The science course was refashioned from a traditional lecture/discussion human biology course into one focused on problem-based learning. Some features of problem-based learning follow:

- It focuses on ill-defined and complex rather than straightforward problems.
- Students work on the problem under study several weeks or months instead of one or a few class periods.
- The entire curriculum is organized around the problems. The problems provide the means for learning academic content rather than serving as an application of knowledge already learned.
- Instructors act as coaches and facilitators, modeling inquiry strategies and helping to guide students' explorations rather than deliverers of content knowledge.
- Students apply academic content to "real-life" tasks.

In studies cited by Arambula-Greenfield on the actual impact on problem-based learning on student learning and motivation to learn, the consensus, overall, seems to be that problem-based learning is as effective as more conventional instructional approaches for most academic and affective outcomes, and potentially more effective for outcomes related to critical thinking, research skills, positive attitudes toward learning, and long term retention.

Constructivist Philosophy

Constructivism is implied in the preceding explanations of inquiry-based and problem-based learning. Inquiry-based and problem-based approaches to teaching and learning science are firmly couched in the constructivist educational philosophy. Both are forms of constructivist teaching.

The constructivist perspective, related to the learning process, involves the active construction of meaning by the learner. How this happens is clearly explained by Neil (1995) in a discussion of how people learn. Neil states that learners

> ...take in new information or ideas, fit it to old conceptions, adapt the old conceptions if needed, and build ever-larger, more sophisticated and complex sets of conceptions, networks of knowledge and arrays of skills. They do so in social context through their interactions with other people. They become emotionally and intellectually engaged, and they reflect on and think about their learning. Teaching adapts to the learner.

According to Farquharson (1995), the value of constructivism for teachers is that it serves as a reminder that each learner constructs meaning and the world differently. These constructions are influenced and supported by the social factors that shape the learner's cognitive development (Staten, 1996). Farquharson recommends that teachers capitalize on this understanding about the learner to form partnerships with their students to help them use their experiences to learn. He continues saying that teachers should also use this reminder to promote the development of active learning and an increased independence on the part of the learner.

According to Diez (1997), "the constructivist (teacher) sees learning as the process of making sense of one's world and teaching as the process of providing learners with the opportunity to develop knowledge, connecting new ideas and experiences with their current understandings" (p. 28). Zahorik (1995) offers a clear conception of teaching using a constructivist philosophy. Zahorik's model includes five basic elements for helping learners do just that. They are: *activating prior knowledge, acquiring knowledge, understanding knowledge, using knowledge,* and *reflecting on knowledge.* These elements can be applied when teaching both declarative knowledge--facts, concepts, generalizations and procedural knowledge--skills, processes, techniques. Each element is briefly described below:

• *Activating prior knowledge*--helps teachers to better plan and provide learning experiences that build on students current understandings and can be used to change students' misconceptions before continuing with the new content.

• *Acquiring knowledge*--teachers help in this process by identifying a few major concepts and making them the center of instruction and by arranging experiences and environments so that students can see the relationships and connections between wholes and their parts.

• *Understanding knowledge*---the teachers role here is to provide experiences that cause students to explore the new content in depth and to share their interpretations of the new content as it relates to their knowledge constructs.

• *Using knowledge*---here, teachers use problem-solving tasks that are authentic, interesting, holistic, long-term, and social as effective means for helping to extend and refine students' understanding by making knowledge functional.

• *Reflecting on knowledge*-- refers to understanding what one knows, or metacognition. Journal writing, teaching what one knows to others, role-playing, and the modeling of reflection are ways teachers employ to provoke metacognition.

Zahorik identifies four types of constructivist teaching that result from these five elements. They are *application, discovery, extension, and invention.* Each one is addressed here to reveal aspects of inquiry-based and problem-based teaching and learning and offer options to teachers (depending on their teaching style and beliefs) for implementing inquiry-based instruction.

Application is evident when the teacher begins by activating prior knowledge, followed by students' acquisition of some content or skill. The teacher then moves to tasks designed to increase understanding. Next, the students engage in these tasks and finally, the teacher employs strategies that cause students to reflect on what they have learned.

In *discovery*, the students engage in a task that has been planned so that student involvement leads to a predetermined outcome. As students engage in the exercise, they either acquire and understand the content or skills incidentally or the teacher provides experiences during the activity that foster acquisition and understanding incrementally. After the activity, other tasks are done that extend students' understanding. A reflection on the new learning also completes this approach.

Extension is similar to application teaching except that the task is divergent versus convergent, i.e., the outcomes are unknown versus known. In a divergent activity the teacher encourages original, creative outcomes. In a convergent activity, the teacher designs the activity so that the students arrive at the predetermined answer or product. Extension, in this case, is inquiry-based learning in that it is not prescriptive and students produce their own, unique conclusions. The teacher begins with "acquiring" and "understanding" tasks, which are used to prepare for the activity that follows, rather than as the main focus of the lesson as in application teaching. These preparatory tasks provide the basic knowledge from which students can pull as they attempt to solve a problem that can be either student or teacher generated. The problem requires the learners to synthesize the basic knowledge in new ways and to extend the acquired new information. After the tasks is completed, the teacher allows for reflection.

Finally, in *invention* teaching, the lesson begins with a "using knowledge" activity. However, in contrast to discovery teaching, the activity requires divergent thinking. In this approach, students experience and try to solve a problem that has multiple answers, rather than one or more finite answers. In working to solve the problem, the students acquire and come to understand content and skills that are needed to reach and support a solution. If students reach a stumbling block, the teacher can provide experiences so that students can continue toward the solution. Invention, as compared to discovery teaching, is more of what a "real" inquiry-based approach to teaching looks like. Each type of constructivist teaching approach described by Zahorik expresses varying degrees of inquiry and includes some of the indicators of inquiry-based teaching and learning compiled as part of this research study (see Appendix A).

Additionally, Zahorik lists several threats to implementing constructivist teaching. First, abruptly changing from conventional to constructivist teaching is unrealistic; he suggests that teachers incrementally substitute constructivist practices for traditional practices. Secondly, to encourage students to join in the process of constructing knowledge, teachers can use tasks that are authentic and build on students' current level of understanding. Teachers also need to value students' ideas, and respect their judgments in order to make this happen.

To achieve content coverage, Zahorik recommends that the constructivist teacher select the most powerful, generative ideas from the content and make them the central focus of instruction. Teachers can evaluate students' constructivist thinking by using assessments that monitor students' progress over time, allow for reflection and provide problem-solving tasks in which students are required to extend and reconceptualize their knowledge in new contexts. Other threats, outlined by Zahorik, that constrain constructivist teaching, but do not prevent its use for teachers willing to try, include class periods that are too short for extensive thought, supervision practices that reward more nonconstructivist teaching, school disciplinary practices that support a behaviorist ideology, and large class sizes. These threats were turned around and included as elements of the framework to move teachers toward and sustain an inquiry-based approach to teaching science.

Constructivism, related specifically to science, shows students actively involved in interpreting and understanding new science content, and connecting this new knowledge to prior knowledge in meaningful ways. Resnick and Chi (1988) provide their definition of constructivism in an article by Lewis Siversten (1993) about the transformation of teaching and learning in science. They state that:

> Constructivisim tells us that people have to build their own scientific knowledge and understanding and that, at each step in science learning they have to interpret new knowledge in the context of what they already understand. We (teachers) cannot teach directly, in the sense of putting fully formed knowledge into people's heads; yet it is our charge to help people construct powerful and scientifically correct interpretations of the world. We must take into account learners' existing conceptions, yet at the same time help them to alter fundamentally their scientific misconceptions.

Use of an inquiry-based (or problem-based) teaching approach can accomplish this.

Brooks (1996), defines constructivism as a way of explaining how people learn. She sees it as both a philosophy and pedagogy that "offers insights into how people construct concepts, search for deep meanings, forge new understandings, and pose and solve problems" (p. 64). She asserts that constructivism directly addresses the issue of how students form concepts and that it is based on the knowledge that learners search for meaning by constructing mental rules that frame their perceptions and inferences. Constructivism helps teachers create classrooms in which students begin to answer questions that they themselves pose (one of the indicators supporting an inquiry-based classroom listed in Appendix A). Brooks (1996) writes that teachers teaching science, using a constructivist approach, view students as scientists wrestling with scientific questions and concepts in much the same way as research scientists. Teachers using this approach guide students to "dig deeply, aesthetically, and responsibly into their current conceptions so that they can critically and creatively examine new conceptions" (p. 65).

A constructivist teaching philosophy is also evident in The Wisconsin's Model Academic Standards for science. It states that "students should experience science in a form that engages them in actively constructing ideas and explanations and enhances their opportunities to develop the skills of doing science" (p. 61).

Recommendations for Moving Teachers

Rakow (1986) asserts that the renaissance in inquiry teaching in science will come when teachers believe that the outcomes justify the effort. As early as 1986, he presented the following recommendations for teachers to begin an inquiry-based science program. These same suggestions can easily be applied, today.

1.) *Start small.* Take one or two chapters of the science textbook (or other resources) and develop good inquiry activities around them. Each year add a few more chapters, leading to a good collection of materials and activities.

2.) *Enlist the aid of other teachers at the same grade level.* Colleagues who teach the same grade level can support and contribute to efforts to implement inquiry teaching. For example, teachers can divide the workload of finding and/or developing lessons that are inquiry-based, and they can share their results.

3.) *Look to the National Science Foundation curriculum projects for guidance.* These curriculum projects identify inquiry-based tasks that could be easily adapted to classroom, school or district curriculum.

The researchers involved in the MIMS project, mentioned earlier, also identify specific supports to implement and sustain an inquiry-based approach to science teaching and learning (Principled Practice in Mathematics & Science Education, 1998). They contend that for students to study science through inquiry, they need substantial grounding over extended periods of time--students need opportunities to pursue a cumulative and coherent curriculum in science, not a series of 2-week units that do not build on each other. Teachers, as well as students, need opportunities to engage in doing science. Teachers need to have a sound understanding of science phenomena, systems, and processes in order to design classrooms that support inquiry in science and develop and provide worthwhile tasks for students. They also maintain that teachers must continue to learn through inquiry in order to present and facilitate learning through inquiry. Additionally, teachers must have a cogent understanding of children's cognitive abilities, especially their own students' thinking. They suggest that teachers work within a professional community that values, promotes and supports teacher engagement in inquiry and knowledge construction in science. And finally, for this approach to teaching to take hold, parents and the community must be informed about the new perspective and new practice and be made aware of its benefits. The thinking is that, if parents and the community see the benefits in the approach they will give their support and encouragement to the teachers, the school and their children.

Sage's and Torp's (1997) article discussing a study conducted by the Center for Problem-based Learning at the Illinois Mathematics and Science Academy offers yet another model that can be adapted for moving teachers toward an inquiry-based science teaching approach. This research explored the question, "What does it take to become a teacher of problem-based learning?" The year-long study concluded that becoming a teacher of problem-based learning requires well-designed professional development experiences that are constructivist in nature. Teachers experienced this learning through the following roles:

- *learner*--to assume roles and grapple with and solve authentic problems.
- *designer*--to learn the critical elements of problem-based learning and its design process with follow-up small group discussions to highlight participants insights, questions and frustrations.

- *coach*--to mentor problem-based learning in action and dialogue with other schools, learn about implementing the strategy in various school settings, present and share their units, and take time to be learners and colleagues by conducting research on a question relevant to them and sharing and discussing the research questions, methodologies and research finding.

To build a community of problem-based learning professionals and support during implementation of the new strategy, teachers team taught and established district problem-based learning teams. They coordinated schedules and reorganized their time to begin implementation of the approach. In terms of professional development, teachers new to problem-based learning needed clear and thorough information that included examples of student work. In their training sessions, participants were put in groups matched by levels of concern and experience and videos or direct observations of problem-based learning was implemented in various settings. Additionally, participants in the study were encouraged by the Center to facilitate site visits and collaborations. A directory was established to encourage networking among the teachers and a listserve was set up to facilitate communication--networks for discussing the problem-based learning.

The study points out that when implementing new approaches to teaching, it is important for teachers to talk regularly with other teachers in the schools, to explain what they are doing and why in order to deal with the reactions of those teachers who may not understand or fully support teachers using the instructional approach. Teachers in the study found discussing their action research and sharing findings with colleagues built credibility for their problem-solving efforts.

Sage and Thorp (1998, p. 35) offer the following guidelines for the challenges of change teachers (as learners) experience when implementing a new teaching approach:

- Model the disposition of learners rather than experts when leading professional development sessions.

- Model the strategies (such as coaching) that you are teaching.
- Encourage teachers to attend training in building teams that include a least two teachers and an administrator willing to explore the teaching strategy
- Provide opportunities to share successes regularly, through presentation of student work, journaling, debriefing sessions, and other forums.
- Provide opportunities to observe as much problem-based learning as possible.
- Provide a safe environment for microteaching experiences in which teachers can test their coaching skills and assess their own effectiveness.
- Continue to mentor teachers in their classrooms when they actually implement their problem-based learning unit.

To sustain such a move, Sage and Thorpe (1998, p. 32) suggest the following supports be provided to teachers committed to the new teaching/learning approach:

- Immerse the teachers in the learning, allowing them, as learners, to investigate and present solutions.
- Mentor them as problem/question designers and allow them to create scenarios for use in their classrooms.
- Mentor teachers as they learn about coaching and then as they actually implement the teaching approach in their own classrooms.
- Encourage teachers to design and conduct action research examining the effects of the teaching approach on their students' learning.
- Summarize research results on the effects of the instructional approach as well as provide multiple opportunities for teachers to dialogue about the strategy.
- Establish various networking options, such as e-mail, distance learning, Internet listservs, studios and resource rooms for local partners and colleagues to build and expand the learning community.

MPS (1997, p. 29) offers recommendations for building a balanced school wide curriculum and structuring the effective teaching of science. These suggestions address several of the concerns identified by teachers for not using an inquiry-based approach to teaching science:

1.) Teachers meet within their building to decide which "teacher selected" units they will incorporate into each grade level.

2.) Teachers at a grade level may share responsibilities for integrating the skills of the various subject areas, including science.

3.) In a school with a laboratory and full time science instructor, instruction would be done with the classroom teacher. The classroom teacher would follow through and extend investigations in the room.

4.) Teachers may divide core and additional units between themselves at a grade level. Each teacher would teach the units they choose to all students at that grade level.

5.) Teachers at a grade level could divide responsibilities for gathering materials, setting up lessons and then share and rotate materials. An education assistant might be responsible for the material and serve as an assistant during the science investigations.

Finally, the Milwaukee Urban Systemic Initiative (MUSI) promotes collaboration as significant action in moving teachers toward an inquiry-based teaching approach (MUSI, 1998). The MSRT's primary goal, through MUSI, is to support the implementation of the MPS science and mathematics content-rich, inquiry-based curriculum with **all** students. They accomplish this by having regular ongoing collaborative meetings with teachers for the purpose of supporting the teachers in their implementation of the curriculum. Actions taken include: planning and teaching content-rich, inquiry-based instruction collaboratively with teachers, sharing information about resources that align with the MPS science curriculum, identifying appropriate materials and resources, informing and strategically planning for professional development, and identifying and providing appropriate professional development aligned with the district's curriculum and standards for teaching science. Collaboration is also evident through MSRT's regular meetings with school principals and other educational leaders of the school for the purpose of discussing the current status of science, sharing ideas about action plans and determining next steps to realize the goals of the initiative.

Research Methods, Sample, and Measures

This action research study used the naturalistic approach to address the research question. It is a qualitative analysis that employed participant observation, an interview survey for focus group discussions, and anecdotal records as data sources (see Table 3). An inventory of indicators specifying inquiry-based science teaching and learning (developed from the literature review and professional development sessions for MSRTs) was used as a supplementary data source to conduct participant observations (see Appendix A).

Table 3. Data Sources

- Classroom observations = 2
- Professional development inservice observations = 4
- Focus group discussions = 4

MSRTs who are familiar with inquiry-based science teaching and learning and whose role it is to collaborate with teachers for the purpose of supporting them in the implementation of the MPS inquiry-based science curriculum, served as volunteer participants in the study. MSRTs were employed as the subjects for this study because of their current understanding and use of some degree and form of inquiry-based science teaching to promote learning. This awareness was used to provide data to compile the inventory of descriptors for identifying an effective inquiry-based science classroom and for developing the framework for moving teachers toward an inquiry-based science teaching approach. MSRTs were also chosen for this study because of their availability and accessibility. Further, observing this group of teachers did not violate any Milwaukee Teachers' Education Association (MTEA) policies and/or guidelines for teacher observation and classroom assessment. Contractually, teachers cannot observe other teachers for evaluative proposes. (The Milwaukee Board of School Directors and The Milwaukee Teachers' Education Association, 1998).

Classrooms taught and/or workshops conducted by MSRTs were observed to assess inquiry-based science teaching. The inventory of inquiry-based science indicators (Appendix A) was used to observe the science classrooms, science-related workshops/inservices and professional development sessions. The descriptors that are defined as inquiry-based science, as well as those that impede this approach to teaching and learning in science, were observed and recorded. An interview survey, specifying questions for the focus group discussions, was developed to identify the supports needed to affect and sustain inquiry-based science teaching. Anecdotal data were also collected, through professional development opportunities, to help build the template of indicators to support an inquiry-based science classroom and to develop the framework for MSRTs, as well as teachers themselves, to use to affect change surrounding the inquiry-based teaching and learning process.

Two (2) classroom observations were made. MSRTs conducted these classroom sessions to support students' science achievement, provide classroom teachers with inquiry-based content-rich science lessons, and to expose classroom teachers to model teaching strategies. Both MSRTs conducted a science investigation dealing with electricity. An average of fourteen (14) students, one (1) MSRT and five (5) teachers were involved in the classroom observations. One teacher, in each class, served as the material preparer and the others assisted students and observed the MSRT as she conducted the lesson. Data obtained from the observations were used to assess inquiry-based science teaching and to identify additional indicators to build the *Inventory of Indicators to Support an Inquiry-based Science Classroom.*

Additionally, four (4) professional development inservice training sessions were observed. MSRTs served as instructors/facilitators in these sessions and the participants were MSRTs and/or classroom teachers. These sessions were conducted to communicate the elementary and middle school curricula (science content and process skills). They included tasks in which the participants built simple and compound machines and constructed simple and parallel electrical circuits. Two (2) performance assessments were conducted, one in which participants served as employees of a design company who were given the task of designing a model of a roller coaster, explaining its unique features, and noting its potential and kinetic energy, friction, and momentum. The second was a simulated videotaped performance assessment where participants, looking at the concepts of erosion and sedimentation, had to determine what happened to a beach that no longer existed in a particular area.

Four (4) focus group discussions were also used as data sources for the research project. The questions used to frame the discussions appear in Appendix B. Two (2) formal and two (2) informal focus groups were used in the study. The formal focus groups were formed and convened by me; the informal ones, were not. The first formal group included the members of the MUSI "Common Eyes" committee, which was established (as part of the MUSI reform effort) to develop an observation tool to be used by MSRTs and teachers to promote "meaningful dialogue about classroom practices in order to improve student achievement" (MUSI, Common Eyes, 1998). This committee consisted of five MSRTs, including myself. Four members were identified for participation in the focus group; however, only two could make the scheduled discussion. The third member addressed the questions, in written form, on her own and the fourth member was not able to participate because of time constraints. The second group included four other MSRTs. Elementary, middle and high school grade levels were represented in these discussions.

Both informal focus groups involved MSRTs participating in professional development sessions. The first one included eighteen (18) MSRTs who were given the task of identifying, "What they would look for in an effective inquiry-based science or mathematics teaching and learning environment." This information was used to help develop the MUSI "Common Eyes" observation tool. See Appendix C for specific information offered by the group of change agents. The second training session was conducted to introduce and to define strategies for successful implementation of a recently adopted inquiry-based mathematics program. Twenty-eight (28) MSRTs participated in this session. Data from all four (4) focus group discussions were considered when building the inventory of indicators for science teaching and learning and when developing the framework for moving teachers toward an inquiry-based approach to teaching science.

Ethics

Ethical issues pertinent to this study were considered. Informed consent to conduct the action research was obtained from the school district, the MUSI leadership team, and the participants of the study. MSRTs involved in the observations, interviews, and/or focus groups were informed of the voluntary nature of their participation and the confidentiality of the research via a consent letter, and again, during the interactions. During the data collection sessions, participants were informed, again, of the purpose of the research study, their right not to participate, their right not to answer questions, and their right to withdraw from the study at any time. This research study posed no risk to the subjects. The subjects can actually benefit from the study by having access to and using the developed framework in their roles as implementors, providers and supporters of inquiry-based curriculum. Their participation in the research may also help them better understand and utilize inquiry-based science to improve their own teaching practice, as well as, assisting others move toward a more inquiry-based approach to teaching. Other MSRTs who are familiar with inquiry-based science teaching and learning, but do not have a proficient understanding of it as a teaching strategy or a framework for assessing effective inquiry-based science in the classroom, can also benefit from the research.

The MPS policies/guidelines for conducting research and the Milwaukee Teachers' Education Association (MTEA) policies and guidelines for observing and assessing classroom teachers were followed. The findings and the practical significance of the research is communicated in clear, straightforward and appropriate language, via this report, for teachers' and the school district's use. The study will be shared with MSRTs, the MUSI leadership team, MPS Research and Assessment Department, and instructors and colleagues in the Alverno College Masters Program.

Findings--Data Analysis and Interpretation of Data

The Observations

The classroom and professional development training observations were quite revealing. The lessons, themselves, were experiential and inquiry-based in nature; however, the approach to teaching the lessons were more of what Moscovici and Holmlund Nelson (1998) described as "activitymania" versus inquiry and what Zahorik (1995) described as application and discovery teaching, which encourages convergent thinking versus extension and invention teaching, which promotes divergent thinking. In both settings, the classrooms with students and the professional development sessions with teachers and MSRTs, prescriptive directions were given or read to the students/participants and materials were identified by the instructor and given to the students/participants. Additionally, the outcomes were known by the teachers, the time to conduct the investigations was restricted, and in some cases, parts of the actual task were done for the students by the teachers.

The lessons for the classroom observations were rich in content. Students were engaged in activity-based experiences to acquire and understand the science content related to closed, simple, and open circuits and conductors and insulators of electricity; however, the classroom observations suggested much more "telling" and doing for the students on the part of the teachers, than inquiry-based teaching promotes. In one classroom observation, students were given the task of building simple, series, and parallel electrical circuits. A diagram of how the circuits should look was displayed on a screen via an overhead transparency throughout the lesson. The MSRT used the diagram during the lesson to explain how the connections were completed. With an inquiry-based approach, the students would experience building the circuits to create their own meaning before the teacher explains and shows them. With such an approach, the students would explain and share their constructions with the teacher and other students. Afterward, the teacher would use the diagram and provide further explanations to correct inaccuracies and misconceptions.

Many instances of teachers directing and telling students how to perform the task were evident during this lesson. As examples, "I gave you the tape so you could connect the wire to your brass fastener," "Your wire is too short," and "One wire is going to be connected to one brass fastener and the other to the battery." However, the teachers did use several focusing, clarifying, and engaging questions during the lesson. This type of questioning made the teaching more inquiry-based because it encouraged critical thinking. Such questions included, "You've been given a bulb, wire, battery, paper clip, brass fasteners, and cardboard--I want you to get the bulb to light up." "What happened to your bulbs when you created your two circuits?" "Did you notice anything different about parallel versus series circuits--did you notice anything different about the bulbs' brightness?" "So what do you think will happen if you add another bulb and why?" "Which type of circuit would you want your house wired as?" However, when some of these questions were asked, teachers also answered them.

On several occasions, the teachers assisting with the lessons actually did the work for the student. The MSRT demonstrated how to cut the wire. One of the teachers told a student where to place and tape the wire, "positive (+) on top, and negative (-) on the bottom," and then proceeded to do it for him. On another occasion a teacher noticed a student having trouble cutting his wire and said, "I'll help you," and began cutting the wire for the student. And finally, when a student questioned the position of his battery and wire, another teacher pointed to the diagram to show the student how the connection should be made, then actually took the circuit board and positioned it for him.

The students, themselves, appeared interested in the task (with some frustrations, initially). About five of the thirteen were actually working on their own; the others were receiving a lot of attention from the teachers. Overall, the students were actively engaged in the task, but they were not asking many "good" questions, explaining, sharing, or working cooperatively (measures of learning). One student, questioning the MSRT about the materials given to him to do the task, said, "But you only gave us....", he was implying that if he had selected his own materials he would have approached the problem another way (multiple approaches and answers are indicative of inquiry-based learning). By the time the students had gotten to the last circuit, they were working more independently, sharing with other students, and answering teachers' questions.

In the second classroom observation students were more involved in "doing" and "discovering" and the MSRT and three of the five teachers served more as facilitators than directors. In this science investigation students were asked to make a switch, electromagnet and a telegraph. They were given handouts showing illustrations of each device and listing the materials needed for each construction, but no prescribed procedures were included. The MSRT pulled together the materials for the investigation, but in this case, the students had to tell the teachers what materials they needed. The teachers then gave the materials to the students, primarily to save time.

The MSRT began the lesson by telling students they would be "brainstorming" to determine how to complete the task on their own. She showed them models of the devices and welcomed students to observe them during their investigations. She told the students to "try has many ways as you can" to make the mechanism work and "talk to each other and help each other" as they proceeded. She encouraged a variety of strategies for solving the tasks.

Students began the task working on their own; however, after about 20 minutes into the lesson, the teachers got more involved by giving students direct instructions and by actually doing some of the work for them. Again, teachers told students what was occurring and what to do. One student asked, "Why does it get stuck?" The teacher tells him. In another case, a teacher asked one of the students, "What have you tried so far?" and before the student could answer, she began to tell the student what to do. And, as a last example, a teacher asked a good extending question to help a student make some generalizations--to situate her understanding. The question was, "Why do you think it might not be working?" The student tried to explain, but the teacher interrupted by giving her directions and telling her to try it and see what happens.

Questions were asked by the teachers that were effective in helping students get at the science content. For example, "What can you tell me about our flow of electricity?" The student answered correctly by saying, "I need a circle." Next, the MSRT asked him, "So what do you need to make a circle?" Through this questioning the student discovered the science concept and was then on his way to completing the task. Other questions were, "So what does that tell you about electromagnetism?" and "What do you need to make your electromagnet work?" The students in this group were much more excited, interactive and talkative than the group described previously. The students were so eager to continue, that when asked to take a break for donuts, they continued to work.

Similar events occurred during the professional development training sessions. The tasks were authentic and meaningful, which helped to facilitate the participants' understanding, reasoning, and problem solving capacities. The participants worked in cooperative groups to complete the tasks. They posed and answered sophisticated and thought-provoking questions related to the tasks. They made conjectures and explored different methods to solve the problems given them. The participants were displaying some of the indicators of inquiry learning (see Appendix A). However, the teaching approach was again more traditional than constructivist and the science and process skills connection was missing. Several of the MSRTs expressed concern that the lessons were conducted using more conventional than inquiry teaching strategies.

For instance, in the beach investigation, participants were given lab worksheets to complete and were told how to complete them. In the roller coaster performance assessment the participants were actively engaged and solving the problem creatively, but the science content was not connected or interpreted. In the lesson where the teachers had to construct a compound machine (a crane) from several simple machines, the teaching approach took on a more inquiry-based teaching and learning style. The MSRT conducting the lesson, at this point, "let them go at it alone," i.e., no prescribed procedure and no direct instructions, unlike what was done during the construction of the simple machines. One of the participants in this training session, who also participated in the focus group discussion said, "This was the point in the lesson where I felt frustrated, but I wanted to continue with the task; I was learning something." Feeling challenged and frustrated is one of the indicators of inquiry-based learning (see Appendix A).

These observations highlight several important considerations that need to be addressed in the professional development of MSRTs as change agents. Teachers and teacher leaders need to serve more as mentors and facilitators of learning in order to help students construct their own knowledge and understanding. There needs to be less telling and instructing on the part of teachers and more reflection and sharing on the part of the learner. The tasks used in teaching and training should require the learners to synthesize, communicate, and extend the knowledge and understanding. Teachers need to become more comfortable sharing control, as well as learning along with the students. They need to create more opportunities for students to share in the responsibilities of teaching. If MSRTs are to be leaders in the district for implementing and sustaining the use of an inquiry-based science (and mathematics) curriculum, they will need to clearly understand the concept of inquiry-based teaching and learning, develop the skills needed for effective inquiry-based instruction and teach/model, accordingly.

The Focus Group Discussions

Formal

Focus groups were used in this study to provide data for developing the framework to encourage and sustain teachers' use of an inquiry-based science teaching approach (see Appendix B for a listing of the questions used to guide the discussions). Analysis of the data collected for the formal focus groups revealed that the MSRTs understand the need for a framework to help move teachers toward a inquiry-based approach to teaching science. They justify this need based on data, current research, and their observations in this area. One MSRT commented that student performance and achievement data show that our (MPS) students are not achieving or performing at the levels expected. If major gaps in achievement are "what we are seeing, then it is obvious that we have to change our approach. We can use this data to show the need for a change in teaching in order to narrow the gap and build a community of learners." Research suggests that inquiry is a powerful tool in learning. Another MSRT commented that, "It (inquiry-based teaching) is effective in helping students learn process and content. It is rich learning--students learn and don't forget what they've learned. The learning experiences are significant." The focus group participants contend that the majority of teachers are not using an inquiry-based approach in their science teaching and that the ones who are, are at the beginning stages of understanding and employing this instructional strategy. They see an urgent need for pedagogical movement along these lines. One MSRT stated that, "Most teachers are not even aware of the inquiry approach and are not doing science very much at all."

The MSRTs involved in this focus group discussion see classroom observation, regular dialogue and discourse between teachers, professional development, modeling, reflection, and district and community level support as essential elements of the change process for improving teacher practices related to science teaching and learning. They believe also, that these elements must occur in conjunction with each other. When asked the question, "What do you think the teachers you work with need to move toward a more inquiry-based approach to teaching science," the MSRTs offered the following ideas:

- confidence in their abilities to understand science and to teach using this approach
- a positive attitude about science and the change process
- the need to value the teaching of science and to understand the value of it for themselves and their students
- opportunities to experience the things that the students will be doing/learning
- more indepth inservices and follow-up once they get back to the classrooms

• a need to see what inquiry-based teaching looks like in the classroom (others modeling/mentoring in a non-threatening manner)
• chances to design inquiry-based lessons/units
• use of inquiry-based curriculum that serves as a professional development tool
• opportunities to reflect on their teaching using this approach and share with other teachers
• continuous use of the MSRTs in their buildings
• MUSI courses and classes (science and mathematics education)

Professional development was a major factor identified in both the literature review and the responses of the MSRTs for transforming science teaching from a traditional approach to an inquiry-based approach. The participants saw professional development in the form of inservice training, workshops, higher-education classes/courses, conferences, professional organizations, and articles as an instrument for helping teachers understand and become comfortable with inquiry-based teaching and learning concepts. This professional development, according to the MSRTs, should provide teachers with continued demonstrations of inquiry-based science teaching as well as observation techniques such as the use of the "Common Eyes" tool for assessing the effectiveness of the teaching. It should also insure that teachers have a deep understanding of science and inquiry-based teaching. Professional development should incorporate a review of performance and achievement data from school districts engaged in the use of inquiry-based teaching in science for data decision-making purposes. Critiques and discussions of literature related to inquiry-based teaching and learning, preparation in the use of inquiry-based teaching, dialogue about the issues surrounding constructivist teaching, understanding performance assessment, and how to integrate science with other subjects should be the focus of professional development sessions to support this pedagogical movement. Included in all professional development should be a reflection component. Through professional development, teachers can practice reflection to aid in their own learning and better learn how to use this skill to change or improve what is happening at the classroom level. As mentioned by one of the focus group participants, "If one does not reflect on what planning was done, what took place in the classroom, how the class performed, and how the students reached the class goals; how does a teacher know where to go in his instruction?"

In terms of what teachers themselves can do to move toward a more inquiry-based approach to teaching, the MSRTs offered the following insights during the discussions. Teachers can conduct grade level meetings to plan, practice using, and evaluate inquiry-based lessons. According to one MSRT, "Teachers have to be willing to relinquish that control and experience the learning with the students; working along side with the kids--building a rapport with them" to make this type of teaching work. They pointed out that teachers can assist in the process and become more knowledgeable about inquiry-based science by taking advantage of the many professional development opportunities and courses offered along these lines. Once the learning and understanding happens, teachers can use this information to modify their classroom practices and lessons to better align with the descriptors of inquiry-based teaching and learning. Also, teachers can utilize inquiry-based resources that take a professional development approach and use these resources, in a book club format, to teach each other.

The MSRTs also saw the need for collaboration as a strategy for implementing and sustaining the use of an inquiry-based science teaching approach. This collaboration can happen through action research and peer observations for the purpose of assessing and improving teaching practices. They suggested that teachers partner with colleagues who have strong science teaching skills to help support their use of this strategy. They recommended that teachers become more involved in science related issues through their schools and district and form support groups through these entities to make effective science teaching happen. A MSRT mentioned that being part of a support group with teachers in her assigned school and forming another support group with other MSRTs, helped her through her first year as a MSRT. Team teaching, mentoring and learning clusters were also given as ways to foster collaboration and collegiality in science teaching and learning.

All agreed that lead teacher roles such as MSRTs, mentor teachers, and peer coaches are necessary to bring about change in science teaching. Lead teachers can assist in this change process by demonstrating effective teaching strategies, modeling, team teaching, and coaching. Another participant stated that, "Lead teachers can help classroom teachers "see it (inquiry-based teaching and learning) and experience it so that they can experience the power themselves and see in their students that they can do it." To expand on this, another MSRT said, "If teachers see (by working with the teacher leader) that this way of teaching engages students in the learning, it will help move them forward. If they then try it and see that it is really working they will continue using it." They believe when teachers see the positive effects of their work in terms of student learning and achievement, they begin to think differently about their students, science, and change itself.

Another focus group participant suggested that MSRTs observe teachers to identify potential leaders who can serve as promoters of science reform (inquiry-based teaching) in their buildings. This teacher would need to be one that the other teachers like and respect, one who is knowledgeable about science, the curriculum and science reform efforts, and one who works well with the staff and is good at pulling people together. A second participant saw the lead teacher role as necessary for helping teachers progress because, "A lead teacher can confirm what it is you are doing, provide you with a base for where to go and how to make that change, and they can enhance what you are doing." Finally, another offered an affective role for the teacher leaders:

> I think lead teachers are absolutely essential, even if the building doesn't have an MSRT. An implementor or someone in the building needs to have this role, because I think teachers need someone to be out there (everyone can't go to each workshop), someone that can go out and gather information and bring it back to the school and share it with the staff. And then too, teachers need that personal touch from someone; someone you feel comfortable with telling them you need help or asking them for advice or direction, how to get concepts across, to bounce ideas off--the personal touch is needed.

To do this effectively, the MSRTs addressed what they need to be change agents for implementing inquiry-based science teaching in the schools. They pointed out that they need "All of the things we listed for teachers," which included more "real" inquiry-based teaching experiences and time for discourse around inquiry-based teaching and learning. A participant said, "We need more dialogue and sharing like this focus group discussion, using questions like these to push us to think. To hear what others have to say and clarify my own thinking (we are somewhat isolated, too). We need feedback (on our practices)." They agreed that they too, need to do more self-reflection to make themselves better MSRTs/teachers.

Support from administration (superintendents, principals, managers, and supervisors) and the larger school community was also mentioned as a need. This can happen with administration setting the tone "right in the beginning and continuing to reinforce throughout the year, that science is important." Formal school and district level committees should also include a voice for pushing effective science education. Additionally, at this level, the support can come by insuring that resources such as the equipment, materials and supplies for teaching and doing science are available and accessible for each science teacher. The district can adopt and purchase materials and programs by publishers that are inquiry-based in nature and that provide teachers with opportunities for experiential learning. School administration can revise teachers' schedules so that at grade level and content area meetings collaboration around inquiry-based science teaching and learning takes place. Parents should also be involved in these meetings. One participant suggested that schools and the district balance and/or eliminate programs, events and extracurricular activities that do not support their goals for effective science instruction and science achievement. He thought this might be considered a radical idea, but he also thought it might be necessary to improve students' overall achievement.

MSRTs stated that schools and the district need to make provisions to insure the training needed to help them move towards an inquiry-based teaching approach. The district can offer professional development that is truly focused and aligned with inquiry-based methodologies and programs. They maintained that the professional development currently being offered by the district, institutes of higher education and community organizations need to connect and focus around the district's vision. "It needs scaling down--there is too much out there and we are burning people out--we only have so much time." The district also needs to look at how professional development is scheduled to "avoid overlap and to see a continuous flow (of learning)." Another MSRT suggested that the entire district focus on one significant aspect of professional development, such as inquiry-based science teaching, science kits and modules, cooperative learning, or performance assessment for a month or longer "so that people are on the same page and getting the same learning." All strongly recommended having "built in networking time" after the professional development experiences.

Regarding school and/or district level structures or policies needed to aid in this change process, two focus group participants indicated that we are at a point in education and in the district where things may have to be mandated to affect change. One MSRT thought that mandatory attendance at inservices might have to happen to get educators well versed on what it is they will be teaching. She used reading as an example, where several years ago the district mobilized all resources around it and the state mandated it as a requirement in teacher education programs to improve students' reading levels. She remarked, "No one every questioned that." She also mentioned that the district should establish a policy for teachers who have lifetime licenses to take classes/inservices or work with "buddy teachers" who specialize in a certain subject matter or proven pedagogical approach to become knowledgeable about current teaching strategies and reforms in education. She asserted, " If we are a community of learners, then everyone should be learning." Another thought that it should be mandatory for teachers to take specific courses in science, mathematics, reading, etc. in order to move up the pay scale. She went on to say that the district administrators could utilize data-driven decision making, looking at students' test scores, to encourage teachers to sign up for professional development classes can also consider making teachers and schools accountable for students' learning. "Eventually, there may have to be district policies stating this is the way it has to be and the principals will have to enforce it in the schools," she remarked.

The community of learners/other stakeholders such as colleges and universities can aid in this change process by continuing to offer classes that "exemplify the inquiry-based approach." One MSRT thought that these institutions should collaborate and commit to teaching preservice teachers using the same approach so that they are prepared to use inquiry-based strategies once they are in the classroom. All thought that colleges and universities can also improve the teaching of science through placing a greater emphasis on science education in teacher training programs. Businesses and community agencies can promote inquiry-based learning by insuring when professionals come in to work with teachers and students, the teaching and learning is an inquiry-based experience. They can also serve as a resource for supplies and equipment needed to "do" science and provide expert knowledge. Finally, the MSRTs were asked, "How can the change be sustained?" They offered the following ideas:

- Teachers, administrators and educators must believe in the change
- More collaboration on developing and delivering instructions
- More dialogue surrounding instructional methods and issues in science
- Continued reflection and evaluation
- Continued support for all

As MSRTs, they see their roles as advocates for science. One of the interviewees commented that "we have to hammer away at the administrators that science is important and professional development has to happen." He added that, forces have to be mobilized for it--a system must be put in place that can continue to encourage the change taking place and address the concerns and problems. Another commented that, "We have to find ways of letting teachers know that they are appreciated when they help the children and we have to help them not lose sight that the change is about the children." And, a third one explained, "We have to also find ways to empower parents so that they know (have an idea about) what is best for their children and have them push on the schools. Parents can work with teachers to see that inquiry-based teaching helps their children."

"The district will need to hire well-prepared teachers and provide inservicing for new teachers coming into the system before they get into the classroom, similar to the Compton Fellowship Program. They should also be informed about what is taking place in the district so that they can use the resources available," another participant noted. Also, groups of MSRTs can be available to move around to inservice new teachers, keeping them abreast of what is happening in the field of science education and making them aware of the district policies related to science achievement.

But, as one MSRT stated, "Teachers' 'thinking' about science teaching and learning will have to change in order to sustain the movement. He went on to say, "We should continue doing what we have been doing in terms of improving staff development related to science education, but with an emphasis on changing the attitudes and beliefs about science teaching and learning. Mindsets will also have to change."

Informal

Anecdotal data from the informal focus groups revealed similar findings as those obtained through the formal focus group discussions. See Appendix C for specific data obtained for MSRTs involved in a professional development session to brainstorm strategies for affecting change in science and mathematics education.

In another professional development session for MSRTs (the second informal focus group), Deann Huniker, of the University of Wisconsin Center for Mathematics and Science and the higher education representative for the MUSI leadership team, using a constructivist approach, had 28 MSRTs work in cooperative groups to answer questions related to their involvement in supporting the implementation of an inquiry-based mathematics program. The questions were:

1. What can MSRTs do in his/her school during the 1998-99 school year?
2. What support do you (MSRT) need?
3. What should MPS be doing as a district during the 1998-99 school year?

MSRTs' responses to these questions were extended to the research question being addressed in this study. The MSRTs' responses again focused primarily on professional development through formal training, teacher observations, modeling, collaboration, and networking. Administrative support through buy-in/promotion, funding, and allowances for teachers to learn the strategy were identified as ways to support implementation of the program. These data appear in Appendix D.

Huniker offered the following recommendations for implementing and supporting a new curriculum:

- select one unit per grade level and form study groups with teachers as they use it with students
- select one investigation per grade level and work with teachers and students
- hold institutes during the summer

- develop an action plan to identify how lead teachers (MSRTs) can help teachers with implementation
- establish district learning clusters
- form a cadre of teacher facilitators to teach summer courses
- offer courses for credit
- conduct a district orientation/presentation introducing the instructional strategy

The Framework

The framework developed through this action research study is informed by the literature review on inquiry-based and problem-based learning and the data collected during the focus group discussions and professional development sessions involving Mathematics/Science Resource Teachers (MSRTs). It identifies the elements, strategies and supports needed to move teachers toward and sustain teachers' use of an inquiry-based science teaching approach. Much of the literature regarding science reform cited teachers' willingness to change and learn, their awareness of the need for change, and their discomfort with current conditions as perhaps most important to the design and implementation of a new instructional approach or school program (Lasley, 1998; Kober, 1993). However, the scope of this research does not address this aspect of the change process related to reforms in science teaching; therefore, it will not be included as part of this framework.

"A Framework to Help Move Teachers Toward an Inquiry-based Science Teaching Approach"

- Curriculum, Instruction, Assessment
- Professional Development
- Collaboration
- Professional Discourse
- Networking
- Lead Teacher Support
- Administrative Support
- Learning Community

The components of the framework include strategies and supports that can be used to encourage and sustain teachers' use of inquiry-based instruction in science. They are detailed below:

Curriculum, Instruction, Assessment

Teachers, curriculum & instruction, and assessment staff can:

- Utilize curriculum, instruction and assessment that is inquiry-based and constructivist in nature.

- Design inquiry-based units/lessons/assessment tasks through school teams, networks with other educators, and formal writing committees.

Professional Development

District and school administrators can:

- Provide professional development that offers continuous and indepth learning, takes a constructivist approach to teaching, models the strategies of inquiry-based teaching, and offers follow-up.

- Provide repeated exposure (opportunities) for teachers to learn through inquiry in order to present and facilitate learning through inquiry.

- Provide teachers opportunities to experience for themselves the science learning they want their students to have.

- Provide experiential learning ('real" inquiry-based teaching experiences) using authentic problems and tasks--ones teachers could actually use in their classroom and that align with the curriculum goals.

- Provide a sound understanding of inquiry-based learning and science concepts and processes.

- Offer opportunities for teachers to see what inquiry-based teaching looks like in the classroom.

- Provide teachers opportunities to reflect on their teaching practices--think about how to change their own classrooms.

Collaboration

Teachers and school administrators can:

- Conduct grade level meetings to develop, practice using, and evaluate inquiry-based lessons.

- Plan and teach inquiry-based lessons collaboratively with teachers--divide up the responsibilities for teaching certain science concepts and processes in the curriculum, gathering materials, and setting up investigations.
- Create opportunities to observe as much inquiry-based teaching as possible.
- Partner ("buddy teacher") with a colleague with strong inquiry-based science teaching skills.
- Conduct peer observations for the purpose of assessing and improving teaching practices.

Professional Discourse

Teachers can:

- Create multiple opportunities for sharing and discussing implementation strategies questions, insights, frustrations surrounding inquiry-based teaching and learning.
- Present and share inquiry-based units/lessons.
- Create opportunities to share successes regularly, through presentation of student work, journaling, debriefing sessions and other forums.
- Share information about resources that align with the inquiry-based teaching approach and the curriculum.
- Critique and discuss literature related to inquiry-based teaching and learning.
- Design and conduct action research on questions relevant to inquiry-based teaching and learning and share and discuss the effects of the teaching approach on the students' learning with colleagues and other educators.

Networking

Teachers and district and school administrators can:

- Set up learning clusters/study groups as forums for encouraging change, continuous learning and collegial discussion.
- Establish networks using communication technology such as e-mail, listservs, to facilitate communication.
- Develop leadership in teachers through school and/or district level networks.

- Join professional organizations and subscribe to professional science education publications.

Lead Teacher Support

Teacher leaders can:

- Mentor teachers in their classrooms when they actually implement their inquiry-based teaching strategies and lessons.
- Model ways in which inquiry has been applied successfully in science classrooms.
- Team teach, peer coach, and provide continued demonstrations of inquiry-based science teaching.
- Provide support through technical assistance.
- Inform teachers about professional development that aligns with the district's curriculum and standards for teaching science.
- Encourage teachers to attend training in building teams (teachers an administrators) to explore the teaching approach.
- Identify teachers in the building who can serve as leaders for promoting inquiry-based teaching as well as science reform.
- Offer teachers the "personal touch" through encouragement, compliments.
- Inform new teachers of the district's efforts and policies related to science achievement.
- Hold regular meetings with school principals and other educational leaders for the purpose of discussing the current status of science, sharing ideas about actions to take to increase students' science achievement.
- Model/take on the role of the learner rather than expert when leading professional development sessions.
- Advocate for science reform.

Administrative/District Support

District and school administrators can:

- Hire teachers who are knowledgeable and well-prepared in science teaching.

- Provide opportunities and time for teachers to work together to plan curriculum and instruction.

- Make appropriate resource materials available and accessible for science teachers.

- Purchase materials and programs that are inquiry-based in nature and that provide teachers with opportunities for experiential learning.

- Establish an environment where teachers are comfortable testing their skills related to inquiry-based teaching to assess their own effectiveness.

- Focus, balance and/or eliminate programs, training, events that do not support science achievement and overall school and district level goals.

- Review science performance/achievement data along with teachers for data-decision making purposes at the school level.

Learning Communities

Teachers, district and school administrators, policymakers, and colleges/universities can:

- Inform (and involve) parents and other stakeholders about the practice and highlight the benefits of the approach for improving students' science achievement.

- Work within and utilize the professional community that values, promotes and supports teacher engagement in inquiry and knowledge construction in science.

- Establish resource rooms or hubs of science education for local stakeholders and educators to build and expand the learning community.

- Ensure that well-prepared teachers, sufficient resources, appropriate facilities, and high quality instructional materials are available to all schools.

- Prepare preservice teachers so that they have a sound understanding of science concepts and principles, inquiry-based teaching strategies, and issues surrounding science education.

- Offer science education courses for credit.

Significance of Results and Carrying Work Forward

This research is intended to provide a framework for moving teachers from conventional approaches to teaching science to a more constructivist approach. The framework developed through this research process identifies needs and offers strategies to assist MSRTs and teachers make a pedagogical movement toward and inquiry-based approach to science.

Additionally, through this research effort, an inventory of indicators describing inquiry-based science teaching and learning was developed. This compilation of descriptors supporting an inquiry-based science classroom can be used by teachers and MSRTs to guide instruction when teaching science and discussing and analyzing classroom practices related to inquiry in school science. It can also serve as a template to be revised and reformatted to meet the teachers' needs when planning and teaching lessons or observing classroom events supporting inquiry-based learning. It can be modified as an observation tool for teachers to employ when conducting peer observations using this teaching strategy. The inventory can also be used as a reference/study guide to better understand and utilize inquiry-based science teaching when conducting professional development workshops and inservices using this instructional approach.

The study will be presented to colleagues, instructors and other educators during a capstone seminar held at Alverno College. It will be shared with MSRTs, the MUSI leadership team, and the MPS Research and Assessment Department. The action research study will also be published through ERIC.

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APPENDIX A

An Inventory of Indicators Supporting an Inquiry-Based Science Teaching Approach

Teaching Practices/Pedagogy

❒ constructivist philosophy

❒ curriculum is: standards-based, skill-based, problem-based, content-rich, integrated

❒ curriculum incorporates content, processes, and products

❒ students' prior conceptions about natural phenomena when planning curriculum and instruction is taken into account

❒ the process of learning--not just what is learned--is important

❒ emphasis on student understanding, reasoning, and problem solving rather than memorization of facts, terminology, and algorithms (active inquiry vs passive acquisition)

❒ worthwhile tasks that enable students to construct and apply their knowledge of key science concepts

❒ depth vs. breath--deeper coverage of fewer concepts

❒ science concepts/principles taught in the context of a personal or social application

❒ instruction that builds on students' experiences, understandings and strength

❒ real world application

❒ diversity and multiple perspectives are valued and utilized to build on the strength of all students

❒ belief that all students are capable of thinking about science

❒ lesson/task is purposeful, directed, authentic

❒ interactivity, such as cooperative and collaborative learning is essential

❒ multiple ways of doing investigation/multiple answers

❒ facilitates discovery learning

❒ long range projects (of a least a week's duration) and conducted in and outside of the classroom

- ❐ appropriate and ongoing use of calculators, computers, and other technologies
- ❐ related field-trips

Teacher Actions

- ❐ helping students to construct their own meaning by modeling, mediating, and coaching
- ❐ acting as mentor and facilitator of learning
- ❐ sharing control and relinquishing role as an authority
- ❐ engaging students in the construction of new understanding through activity-based experiences and hands-on instruction
- ❐ helping students clarify their thinking and modify their plans for inquiry
- ❐ designers, ensuring student engagement with and understanding of worthwhile content
- ❐ building on students prior knowledge and understanding
- ❐ creating opportunities for students to share knowledge and responsibilities
- ❐ providing tasks/experiences that are of relevance and interest to students
- ❐ asking thought provoking, insightful questions to set the direction of study and guide students through the inquiry process
- ❐ asking questions of students during and after investigation:

  •what did you do?
  •how did you do it?
  •what did you discover?
  •what did you see?
  •what do you think it means?
  •what new questions do you have?
  •what is next?

- ❐ encouraging and accepting a variety of strategies for solving problems
- ❐ encouraging students to give evidence and scientific arguments to support their conjectures and conclusions
- ❐ using cooperative learning techniques to promote interactions and deeper understanding
- ❐ taking time to listen to what students think about a concept and designing the lesson accordingly
- ❐ learning along with students (experienced co-learners)
- ❐ providing ongoing feedback

Teacher Feelings

- ❐ intellectually challenged
- ❐ enjoying the intellectual challenge
- ❐ perturbed by the intellectual challenge
- ❐ learning a lot
- ❐ flexible

Student Actions

- ❐ actively engaged
- ❐ solving problems creatively
- ❐ making conjectures and exploring possible methods to solve problems
- ❐ using a variety of strategies for solving problems
- ❐ constructing own knowledge/meaning
- ❐ learning from each other,collaboration--to help people learn from the varied perspectives of their peers and the teacher.
- ❐ serving as teachers
- ❐ thinking critically and logically about relationships between evidence an explanations
- ❐ using science in ways that scientists do in the real world
- ❐ discovering science concepts and connections
- ❐ constructing and analyzing alternative explanations
- ❐ engaging in reflection
- ❐ applying/transferring knowledge and understanding to other situations
- ❐ careful interpretation and deep understanding of the content and processes in contrast to the ability to reproduce information
- ❐ posing and answering sophisticated questions
- ❐ posing questions using critical thinking and reasoning skills
- ❐ working on personal or group question(s)

- ❐ generating new questions from the initial questions
- ❐ giving multiple answers--and they are accepted
- ❐ demonstrating skills being developed and learned
- ❐ participating in self- and peer- assessment
- ❐ communicating their understanding/learning of science concepts using scientific language/terminology
- ❐ using a science concept/principle to explain what they have done in an investigation
- ❐ clearly communicating their ideas and solutions using a variety of media & tools
- ❐ engaging in meaningful discourse/discussing findings with teacher and other students
- ❐ communicating scientific arguments
- ❐ writing out reasoning used to solve problems
- ❐ using evidence and strategies for developing or revising and explanation
- ❐ using appropriate resources, tools and techniques to discover, solve problems gather data
- ❐ manipulation of a great variety of materials
- ❐ engaging in complex, real-life projects
- ❐ planning and conducting scientific investigations/experiments
- ❐ developing scientific thinking skills (hypothesizing, controlling variables, making observations, collecting and analyzing data)
- ❐ developing procedures and lists of materials and equipment vs. following prescribed procedures
- ❐ interpreting results as there are no prescribed findings

Student Learning

- ❐ all students are involved in doing and understanding science
- ❐ building knowledge while doing and learning science
- ❐ developing higher order cognitive skills

- understand that learning is social
- novice learning to be an expert
- using discrepancies as entry point for inquiry
- viewing science as patterning the world
- viewing science as integrated, continuous, and even
- many problems/issues have multiple points of view
- making learning public to build on knowledge

Student Feelings

- intrinsically motivated--using "I want (or we want) to find out"
- excitement and pleasure from learning
- challenged intellectually and looking for balance
- perturbed
- value the skills to work with others

Assessment(s)

- is an integral part of instruction
- meaningful, challenging experiences
- evaluate student's new understanding
- long-term
- process-oriented vs product-oriented (right/wrong answers)
- criteria/rubrics and or tools generate knowledge and are used to develop research question or assess experimentation
- student and teacher created
- authentic

Science Investigation

- ❒ real problems, some are ordinary and some are extraordinary
- ❒ science process skills are emphasized and taught in context
- ❒ science problems/hypothesis arise from students (investigators) questions and are based on their experiences
- ❒ material collection/preparation is students' and teachers' responsibility
- ❒ materials for science investigations are given upon students' request/chosen by students vs ready to go (e.g. kit)
- ❒ deciding what data to collect and how to organize it
- ❒ is complex and involves sustained amounts of time
- ❒ time is made available for repetitions or revising the experiment
- ❒ results/correct answer from science investigation are unknown by teacher, students, or text
- ❒ multiple results are negotiated and discussed
- ❒ results are presented to other investigators for criticism

APPENDIX B

Interview Survey Focus Questions

1. Where do you think the teachers you work with are in their use of an inquiry-based approach to teaching science?

2. Where do you think the teachers you work with are in the change process related to reforms in science education?

3. If changes have occurred in the teachers you work with in terms of overall science teaching (i.e., teaching science more often, teaching science non-traditionally, using more hands-on activities/laboratory work, science inquiry) how do you account for these changes? What did you do for these changes to occur?

4. What do you think the teachers you work with need to move toward a more inquiry-based approach to teaching science?

5. What type of professional development do teachers need to move them toward an inquiry-based science teaching approach?

6. What can teachers do to help move themselves toward an inquiry-based approach to teaching science?

7. How does teacher attitude/beliefs (about children, themselves, learning, science, pedagogy, instructional strategies, reform ideas/efforts) play a role in moving teachers toward this change?

8. What can teachers gauge from their students to see and understand the need for an inquiry-based approach to teaching science or to help facilitate their move toward this type of teaching (e.g., analysis of student work and students' performance/achievement, assessment of student learning, student feedback).

9. How do we, as Mathematics/Science Resource Teachers (MSRTs), justify the need for an inquiry-based approach to teaching science?

10. Are lead teacher roles, such as MSRTs, mentor teachers, peer coaches, necessary for bringing about such as change? If so, how can they facilitate or how have you facilitated the change?

11. What do you need as a change agent/teacher leader to help guide and support teachers toward use of an inquiry-based science teaching approach?

Interview Survey Focus Questions (con't.)

12. What school and/or district level structures or policies need to change to aid in this process?

13. How can the community of learners/other stakeholders such as colleges, universities, policymakers, businesses, and community agencies aid in this change process?

14. How do you see collaboration/dialogue/discourse as a strategy for moving teachers toward an inquiry-based approach to teaching science?

15. How do you see modeling as an approach to help move teachers toward an inquiry-based approach to teaching science?

16. How do you see teacher observation as a strategy for facilitating the process?

17. Do you think reflection is valuable in this reform and other change processes? Explain.

18. How can the change be sustained?

APPENDIX C
MSRT Professional Development
Session #1

- vision setting for science involving all stakeholders
- define and clarify the curriculum
- build teams to identify and solve problems
- focus on the things that are working
- remove the blockers/barriers to get at the target
- look at policies/structures in place for science reform--ones that support reform, expand them--those that do not, eliminate them
- focus on the teachers who want to make change-identify them as leaders to help bring others on board
- identify specific strategies to affect change, move/change teachers
- complete a teacher needs assessment and offer training, accordingly
- establish rapport, build relationships, offer encouragement, support, compliments
- train teachers in constructivist, project-based, inquiry-based approaches to teaching science
- provide training in teaching/learning strategies, curriculum, assessment
- show teacher what a good/effective science classroom looks like:
  --videotape teacher and classroom and assess what occurs
  --observe effective teachers using an observation tool
- establish more interaction/dialogue between teachers and principals
- have teachers observe MSRT doing the lesson, first--modeling
- teacher self-reflection
- teacher can practice with MSRTs--gaining more experience conducting inquiry-based lessons
- MSRTs identify what they value (qualities/behaviors/dynamics) in a effective science classroom to promote conversation
- ask teachers a lot of probing questions to get teachers to think about/identify what they mean; investigate further to get at what teaches are saying and feeling
- provide access to reading materials/resources/articles related to inquiry-based science
- ask teachers what they would look for, what they think inquiry-based science teaching looks like, is?
- identify one aspect of inquiry at a time to focus on and offer to work on it/model it for the teacher

APPENDIX D

MSRT Professional Development
Session #2

1. MSRT Actions

- facilitate inservices for all teachers
- awareness
- talk it up
- help teachers plan and implement lessons/units
- encourage professional development
- "mini" pilot with interested teachers
- form networks/learning clusters among schools--promote collaboration
- show connections between the WSAS assessment and what students are learning via inquiry-based approach
- promote related university/college courses
- show how curriculum has commonalities with what teachers are already familiar with and using
- model lessons that are inquiry-based
- team teach using inquiry strategies
- observe teacher conducting lesson using an observation tool to identify inquiry and complete observation with a conference
- meet with and/or train parent groups, conduct workshops for parent groups using the approach
- make teachers feel comfortable and not threatend to teach it

2. What MSRT needs

- support from leadership
- leadership listening to and implementing suggestions
- own training/inservices/staff development in area
- ongoing experiences using the approach
- more dialogue on concepts and research
- support by "buddying up" with teacher proficient in approach
- principals' endorsement/support
  - -using staff and grade level meetings to address curriculum
  - -informing staff that they are expected to use curriculum
- study and practice using approach
- receive professional development information early to pass on to teachers

3. District Support

- district buy-in
- district PR promoting inquiry, early on, to parents, community, business
  - -Superintendent statement supporting the instructional strategy
- funds for professional development/staff development courses
- provide paid inservices
- professional development beyond an introduction to the program/teaching
- recruit/identify teachers willing to "push," "sell" the program--provide means for them to spread the word (vehicles, etc)
- include all supports in the district--Title 1 personnel, superintendents
- develop assessments that support the method of teaching and learning
- train administrators to heighten the awareness and understanding of the curriculum to be used in their buildings--active participants in the program via staff meetings or principals meetings
- keep lines of communication open among stakeholders (MSRT, teachers, principles, schools)
- provide schools with First class/MPSnet (computer software) to facilitate networking for both teachers and students as they try teaching approach
- find teachers/students/classrooms to conduct demonstrations using the teaching approach, teachers visit other teachers to see how they (others) are implementing the strategy (video production possibility)
- principals need to give teachers room, space, freedom to try/experiment with the teaching style/curriculum
- extend class period to teach lesson

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