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Inservice teachers' implementation of the Science Writing Heuristic as a tool for professional growth

Sozan H. Omar

Iowa State University

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Inservice teachers’ implementation of the
Science Writing Heuristic as a tool for professional growth

by

Sozan H. Omar

A dissertation submitted to the graduate faculty
in partial fulfillment of the requirements for the degree of
DOCTOR OF PHILOSOPHY

Major: Education

Program of Study Committee:
Brian M. Hand, Major Professor
Frederick O. Lorenz
Thomas Andre
Thomas Greenbowe
Lenola Allen-Sommerville

Iowa State University
Ames, Iowa
2004
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Sozan H. Omar

has met the dissertation requirements of Iowa State University
DEDICATION

To my husband, Dr. Mohammad Khiyami, for all his support and encouragement.

To my kids, Anamil, Abdulaziz, and Neam for their love and patience.
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ABSTRACT

According to the National Science Standards, science educators have been calling for the inclusion of inquiry-based approaches in science classrooms as a reform for science instruction. Teachers’ reluctance to implement inquiry-based approaches may be attributed to the different interpretations of the underpinning theory. Any efforts to help teachers implement effective teaching approaches, therefore, should not target merely additive skills; rather, such efforts should foster fundamental changes of beliefs, knowledge, and habits of practice that teachers deeply hold.

This study is a part of a bigger project known as the Science Writing Heuristic (SWH) Partnership Professional Development Project, conducted at Iowa State University in association with the Iowa Department of Education to help improve science teaching. The aim of the project is to help in service science teachers understand and apply a student-oriented instructional approach, using the SWH. The framework of the SWH emphasizes the role of classroom dialogical discussion in students’ learning. The role of the teacher when implementing constructivist approaches represented in a student-oriented instruction, differs markedly from traditional approaches, and hence there is a need to study the changes in teaching practice when using this specific tool.

The methodological framework of this study combined qualitative and quantitative methods. Interpretative case studies for 18 science teachers are presented. A triangulation strategy was used to provide support for the qualitative findings using three different data collection approaches: observation, questionnaire, and interviews. Quantitative data in the form of student performance on higher order conceptual questions and total test scores were collected.
Teachers varied in their implementation of the SWH. Three criteria were constructed to define teachers' levels of implementation: epistemological belief, pedagogical practice, and teacher content knowledge. Different components were included within each criterion, with three scales used to rank each teacher's implementation within each criterion.

The study is pointing to the importance of assisting science teachers with effective pedagogical strategies if there is to be an impact on students' performance on tests. This project was undertaken with partnerships between schools, Area Educational Agencies, and the University. Such partnerships need to be built to promote successful change to science teaching.
CHAPTER ONE

Introduction

General Overview

Four decades after Joseph Schwab (1964) introduced the idea that science should be taught as an inquiry into inquiry and almost a century since John Dewey advocated classroom learning as a student-oriented process of inquiry; science teachers and educators still struggle to achieve such practices in the science classroom. An inquiry goal for science education allows for implementation of epistemic goals that focus on how we know what we know and why we believe it to be of better-quality than other competing beliefs (Duschl & Ellenbogen, 2002).

As scientific knowledge is often presented in an idealized form that can be described “as a pure abstract method of proceeding, decontextualized from the choices, values, and institutions which motivate and constrain our proceedings” (Lemke, 2002, p. 1), there is a need to change the current science teaching practices to accomplish much more than simply detailing what we know (Minstrell & Van Zee, 2000; National Research Council, 2000). Educators argue that students need to be involved in forms of classroom communication that model the discourse that occurs in scientific communities (Schauble, Glaser, Duschl, Schulze, & John, 1995).

Duschl and Ellenbogen (2002) argued that the design of learning environments must be shifted from merely concept and process learning to epistemic and communication learning. Such a shift requires a new focus on science teaching—that is, to emphasize how evidence is used in science for the construction of explanations. In other words, the construction of argument and discussion in science classroom will not only help students
understand the scientific concepts, but also enable them to recognize the strengths and limitations of scientific argument (Osborne & Young, 1998). In supporting this discussion Siegel (1995) asserted that

Argumentation . . . is aimed at the rational resolution of questions, issues, and disputes. When we engage in argumentation, we do not seek simply to resolve disagreements or outstanding questions in any old way . . . Argumentation . . . is concerned with/dependent upon the goodness, the normative status, or epistemic forcefulness, of candidate reasoning for belief, judgment, and action. (p. 162)

A significant challenge for science teachers is to create inquiry learning environments that promote an authenticated context for student discourse. This will require changes in teachers’ current practices.

A lack of success when implementing new instructional strategies may be attributed to failures of poor implementation that emerge from different interpretations of the underpinning theory behind the new instructional tool (Windschitl, 2002). Thus, any efforts to help teachers implement new teaching approaches should not target merely additive skills; rather, such efforts should foster fundamental changes to beliefs, knowledge, and habits of practice that teachers hold deeply.

**Rationale**

Researchers in science education have adopted the philosophy that in order to address student conceptions, which are scientifically incorrect, teaching strategies centered on direct instruction or lecturing can no longer be used as the basis for generating conceptual change. Students do not simply absorb "knowledge as it is presented, but impose their existing frameworks of knowledge to incorporate and invent new knowledge" (Putnam, Lampert, &
Peterson, 1990). Thus teaching strategies used in the classroom need to allow students the opportunity to engage their knowledge and be active participants in the learning process in order to support the construction of new knowledge.

Teachers need to change from current practices which are orientated toward information transfer (Tobin & Fraser, 1990) where emphasis has been placed on "rote learning of ill-organized facts and practice on isolated skills" (Brophy, 1989, p. xi), to practices which foster changes in "learners' epistemologies" (Duschl & Gitomer, 1991, p. 847). These changes will require teachers to examine their current practices in order to implement student-oriented rather than teacher-oriented approaches within science classrooms.

Several studies have been conducted within the framework of professional development programs to assess inservice and/or preservice science teachers changing to student-oriented approaches. Promoting argumentation in science classrooms requires teachers to develop appropriate pedagogical strategies in order to scaffold student discourse. The propose of this study was to study science teachers' implementation of constructivist teaching/learning approaches that support classroom argument within authenticated inquiry environments.

**Purpose of the Study**

This study was conducted within an inservice program with a group of science teachers from different school districts involved in teaching upper elementary, middle, and secondary classes. The study was implemented with the intention of enhancing the use of student-oriented teaching/learning approaches. The framework of the study as recommended by the science writing heuristic (SWH) emphasized the role of classroom dialogical
discussion in students’ learning. The role of the teacher when implementing constructivist approaches differs markedly from traditional approaches, and hence there is a need to study the changes in teaching practice when using this specific tool.

The purpose of the study was fourfold: a) to support teachers’ shift from teacher-oriented to student-oriented approaches within a professional development program; b) to understand how teachers implement a new teaching approach that requires the promotion of student argumentation discourse; c) to help science teachers adopt and effectively apply the science writing heuristic (SWH) as a tool to implement a student-oriented approach within the framework of an inservice professional development program, and; d) to understand the effect of the various levels of teacher implementation on students’ understanding of scientific concepts.

Therefore, the goals that direct the study planning include the following:

1. To diagnose the changes in teaching practice necessary for implementing the SWH as a student-oriented approach.

2. To detect the effectiveness of such an approach on student learning of scientific concepts.

3. To develop a set of criteria to evaluate teacher progress as s/he implement these approaches.

**Research Questions**

The shift to constructivist approaches required changes in both the teachers’ pedagogical knowledge and their role within the classroom. The study examined the effect of the inservice program in relation to changes and the cause of the changes, in teachers' classroom practices. The research questions that guided this study included the following:
1. To what degree does the inservice professional development program enable each teacher to adopt and implement the SWH as a student-centered approach within their classrooms?

2. What is (are) the main characteristic(s) that define(s) different levels of implementation of the SWH?

3. What is the effect of teachers' levels of implementations of the SWH on students' learning of science concepts?
   
   (a) Is there a difference in student learning due to teachers' levels of implementations of the SWH with respect to student gender?
   
   (b) Is there a difference in student learning due to teachers' levels of implementation of the SWH with respect to student achieving abilities?

Dissertation Overview

Chapter two examines the relevant literature to provide a theoretical framework for the study. The theoretical framework defines the basis for choosing the SWH as a tool to shift teacher instructional practice to a student-oriented approach. The chapter has been divided into four sections: constructivism, argument, writing in science, and professional development.

Chapter three describes the research method adopted as well as detailed information of the professional development program. To provide a clear description of the research method and the structure of the study the chapter has been divided into five sections: methodological framework, qualitative research design, criteria for levels of implementation and ranking mechanism, professional development program, and quantitative research design.
Chapter four and five are the results. Chapter four includes descriptive information of all participating teachers and the unit(s) implemented including the big ideas, SWH activities, and conceptual questions. Chapter five is organized into two segments: qualitative and quantitative results. The qualitative result segment is organized in three sections based on the three levels of SWH implementation quality. In reporting this, each teacher’s case study is reported separately. The quantitative results include the statistical results conducted for selective cases of teachers ranked in different levels of the SWH implementation quality.

Chapter six presents the discussion of the criteria upon which the researcher based her teacher ranking in association with Hand’s (1996) model for diagnosing inservice science teacher professional development and Simon’s (1995) model for teaching from a constructivist approach. Finally, chapter seven addresses the limitations and implications associated with conducting a professional development study using the SWH as an inquiry-based tool.
CHAPTER TWO

Literature Review

This chapter examined the literature in relation to the study in order to provide a theoretical framework for answering the research questions. Further, this chapter served as rationale for arguing the importance of adopting constructivist learning/teaching approaches as recommended by the science writing heuristic tool. The chapter is organized in four segments labeled constructivism, argument, writing in science, and professional development. In the first segment—constructivism—two issues are discussed: constructivism as a learning theory (an attempt to define the different philosophical positions beyond constructivism) and educational implications which highlighted: conceptual change model, constructivist teaching model, and teacher role. The second segment—argument—defines the origin of argument as a theory and the rationale beyond embracing such discourse in science classrooms. Two main issues were addressed: argument and constructivism and argument in science education. The third segment—writing in science—is devoted to the use of writing-to-learn strategies in science classroom to promote more learning, including the science writing heuristic (SWH). The last segment highlighted in this literature is the professional developments required in adopting constructivist teaching approach.

Constructivism

Constructivism as a Learning Theory

Constructivism as a learning theory is derived from the philosophical position, which questions the ontic reality of knowledge and how one becomes to know. Whereas knowledge does not exist independent of the knower, constructivist philosophers argue that objective reality does exist; however, the knower has no direct access to that reality. In other words,
knowledge cannot be discovered. Rather, it is constructed in the mind of observer/knower (Driver & Oldham, 1986). Human beings construct their knowledge as a result of their attempts to create meaning of their experiences and to explain the world around them. Therefore, what one knows corresponds to the reality as seen through the lenses of the observer, which reflects the degree of certainty of knowledge and implies the limitations of the methods used to construct it (Simon, 1995). To know means that we cannot separate ourselves as observers from our observations. This reflects the subjective nature of human knowledge (von Glasersfeld, 1990; Zahorik, 1995).

According to Strike (1987, p. 483), the basic assumption of constructivism—learning is a constructivist activity that the learners have to carry out themselves—becomes “uninteresting because almost no one, beyond a few aberrant behaviorists, denies it.” In the late seventies, educators accepted the idea of the active role of the learner in defining knowledge with respect to his or her experiences, whether in isolated settings where no interaction with others occurs or in social contexts (von Glasersfeld, 1988).

Regardless of the learning context, the process of knowledge construction results in the development of a learner’s conceptual structure where new knowledge is generated. Strike and Posner (1982) commented on the role of conceptual structures in knowledge generation:

The nature of these concepts [conceptual structures] significantly determines what is learned and how it is learned. Moreover, learning is not just a matter of adding to one’s store of concepts. It transforms them in some way. Neither the learning of the individual nor the production of new knowledge by an intellectual profession is the mere accumulation of new facts. (p. 232)
Constructivism as a learning theory, therefore, emphasizes the role of the learner's existing conceptual structure in making sense of the new learning experience.

Based on the emphasis placed with respect to the knowledge, Moshman (1982) posited three views of constructivism: exogenous constructivism, endogenous constructivism, and dialectical constructivism. Each view highlights a different perception of the nature of human knowledge, which in turn results in different educational implications of the theory.

Henriques (1997), on the other hand, outlined four faces (interpretations) of constructivism: information processing, interactive constructivist, social constructivist, and radical constructivist. Each face implies different interpretations of the power relationship between teacher and learner. Such relationship could be defined on a continuum of "decreasing teacher structure and increasing learner control" (Henriques, 1997, p. 3).

According to exogenous constructivism, to construct knowledge is to restructure knowledge that exists in the external world, thus emphasizing the external milieu, such as experiences, teaching, and exposure to models, in the 'acquisition' of knowledge. As Schunk (2000) stated, "knowledge is accurate to the extent it reflects external reality" (p. 231). Information processing is the best image of such a view, where the learner can construct meaning of the objective reality from his/her teacher or experience. This meaning, however, must be in harmony with the already existing conceptual structure of the learner; otherwise, the learner will need to change his/her ideas to account for the difference represented in the objective reality.

From this perspective, information processing is considered a constructivist activity because the learner is involved in a continuous "goodness of fit" between the new stimuli
caused by the new encountered phenomena and his/her conceptual structure (Fisher & Lipson, 1985; Henriques, 1997). This view puts more emphasis on the external world or “nature as the instructor” (Phillips, 1995), which implies that knowledge can be discovered. Nevertheless, such view “hardly warrants the label “constructivism” at all” (Phillips, 1995, p. 7), because the mind plays a passive role in creating ideas of its own.

Endogenous constructivism, on the other hand, reflects the extreme opposite to the exogenous view by placing all emphasis on the learner’s internal cognitive action in structuring new knowledge. Knowledge does not reflect the external reality; rather, knowledge is created based on the prior structure of the learner (Moshman, 1982), developed through the cognitive activity of abstraction, and follows a generally predictable sequence (Schunk, 2000). Thus, a learner would make sense of his or her experience in his or her own way based on the culture and prior knowledge (Henriques, 1997). Piaget’s (1970) cognitive developmental theory may fit within this view, since he rejected the idea that knowledge preexists in our minds (innate) or can be gained directly from experiences while asserting the role of mental structures of the mind as the main source of our understanding of the world.

In support of this theory, von Glasersfeld (1991) stated the following:

The results of our cognitive efforts have the purpose of helping us cope in the world of experience, rather than the traditional goal of furnishing an “objective” representation of the world as it might “exist” apart from us and our experience. (p. xiv-xv)

Dialectical constructivism (Moshman, 1982), as interactive-constructivism (Hennessey, 1994; Shymansky, 1994), falls somewhere in the middle between the exogenous and endogenous constructivism. In dialectical constructivism, the construction of knowledge
is still considered as an active process in which the learner based on the interaction with the physical world and/or others involves in an internal dynamic construction of knowledge (Phillips, 1995). This view argues that knowledge reflects the outcomes of mental contradictions that result from interactions with the environment, which emphasizes the embodied role of two knowledge aspects: private knowledge and public knowledge, as a resolution of such contradictions (Henriques, 1997; Moshman, 1982; Shymansky, 1994). The public aspect of knowledge reflects the learner’s interaction with the physical environment and/or other people, whereas the private aspect refers to the learner’s attempt to generate meaning or make sense of such interaction. Such interactions are limited by the learner and the procedure, or the context, in attaining an accurate interpretation of the real world. At the same time, dialectical constructivism stresses the need for continuous evaluation of all knowledge constructions (Hennessey, 1994; Prawat & Floden, 1994). Zeidler (1997) asserted the importance of the continuous evaluation of knowledge construction in the following:

The idea of dialogic interaction and argumentation involves attempting to find a fit among one’s beliefs, other individuals’ beliefs, and the problem solving task at hand . . . . This view holds that change in the way people think does not happen in incremental linear steps: rather mutual factors (other’s perspectives) continually restructure, alter, or fine tune a students’ goals, procedures and personal knowledge. (p. 485)

Social constructivism, as a different interpretation of the theory, (Henriques, 1997) can be located somewhere in the middle of the spectrum between dialectical and endogenous constructivist. From this view, nature as instructor is not as important as humans as creators (Phillips, 1995). McCarthy and Raphael (1992) stated that “knowledge is constructed
through consensus by communities of knowledge peers,” a stance which rejects the existence of an “objective reality that can be measured or mirrored” (McCarthey & Raphael, 1992, p. 16) and denies individual construction of reality. Therefore, the main source of knowledge is society (Prawat & Floden, 1994) where “knowledge is one in which validity is established among alternative interpretations by group mediation” (Henriques, 1997, p. 7).

In general, constructivism is not a philosophical position of viewing truth and reality; rather, constructivism is a learning theory upon which one may define his or her approach of viewing truth. Different interpretations of the theory have been defined according to the different perceptions of viewing reality. Information processing, interactive-constructivism, social constructivism, and radical constructivism are four faces of constructivism defined on the continuum spectra based on the power relationship between the learner and the teacher. Each face underlies different assumptions about knowledge, learning, pedagogy, linguistic, and classroom practice.

Further, objectivism, realism, and relativism, on the other hand, are three philosophical positions addressing the ontology of the concept of reality and truth. Objectivism believes that truth is independent of the context in which they are observed; relativism, in opposing such position, questions whether a truly unbiased observer ever exists. Positivism, on the other hand, demands observational evidence in a sense form to believe in truth. Thus, the most important issue is that among all these views of reality and/or philosophical positions fall the premises for science education. Yet, what should science educator place more emphasis upon?
Implications for Science Education

Translating theory into practice is always presenting challenges, in education or in any other domain—knowing does not mean applying. Further, when multiple interpretations of the theory exist, the task becomes much more demanding (Shymansky et al., 1997) hence; each interpretation of the theory supports different philosophical position, which is crucial to science education because each interpretations underlines different assumptions about science knowledge, learning, pedagogy, linguistics, and classroom dynamics, which, in turn, reflects different instructional approach (Henriques, 1997; Yore, 2001).

Nevertheless, mature scientific knowledge, of the form that commands widespread consent, does not differ according to the pedagogical position adopted by a scientist or a science educator. Understanding this position is crucial to the field of science education because

The process of learning science, unlike any other field, involves reaching a position where the student has understood enough of the shared, and temporarily accepted, store of knowledge so that he or she can communicate with others and even make contribution to the general scientific consensus. (Scerri, 2003, p. 474)

In stating this, Scerri argued that the constructivism that educators have been appealing for in science education stands solely for the learner’s construction of scientific knowledge, which excludes the construction of mature scientific knowledge (Scerri, 2003). Chinn and Malhotra (2002) discussed a similar idea when drawing an analogy of classroom tasks (inquiry) to authentic scientific research; although both shares similar epistemology, the goals of each are different. Scerri further explained the difference stating that,
[when using] concepts like constructivism or relativism, which are essentially being borrowed from philosophy and sociology, they [science educator] need to make it quite clear that it is not the same brand of constructivism or relativism that they are supporting in the context of pedagogy. (Scerri, 2003, p. 474-475)

The following discussion highlights similarities and differences in pedagogical practice of each face of constructivism. Cobb, Yackel, and Wood (1992) described three main components to reflect the pedagogical practices of teachers who adopt information processing approach. These are

- The goal of the instruction is to show students relationships that are located outside of their minds.
- Direct instruction should help student construct his/her internal relationship.
- External instruction materials are the main sources for the knowledge.

On one hand, information-processing and interactive constructivism share a common aspect of learning as being “public knowledge” where students are involved in activities and learn through interacting with the physical world and/or other people. The two views, however, differ on “private knowledge,” where meaning is formed when students individually reflect on and make sense of their interactions. Interactive constructivism, in contrast to information processing, encompasses inquiry teaching models to promote higher-levels of thinking and supports teaching for big ideas and unifying concepts. At the same time, interactive constructivism does not “rule out” the role of direct instruction if imbedded in authentic context of inquiry and only if provided when needed; however, “only when students have time for both the public and the private phases of learning are they able to reconcile their previous ideas with their new experiences.” (Henriques, 1997, p. 5)
On the other hand, there is an overlap between interactive and social constructivism with respect to the role of public knowledge. While both views acknowledge the role of interaction with the physical world and/or others in knowledge construction, social constructivism denies the private component of knowledge construction. Hence, individuals only construct knowledge embraced by their culture and/or community (Henriques, 1997; Yore, 2001). By contrast, the interaction with the physical world and/or others is the shared aspect between radical and interactive constructivism. But, while interactive constructivists emphasize the role of interactions and contexts as judgmental criteria for the knowledge, radical constructivists highlight the self as the judgmental criteria. The crucial and important component, however, of all constructivist-learning theories is that learning is taken as an act of making meaning (Simon, 1995; Strike, 1987).

By adopting interactive constructivism and recognizing the role of public knowledge in shaping individual knowledge, Driver (1990) argued that, although the construction of knowledge differs from one individual to another based on prior knowledge and experience, individuals’ knowledge would share similar meaning. Individuals use language to express their thinking and to communicate with each other. Since language cannot be used as a means of transferring thoughts or meanings, a process of negotiation is needed in order to reach consistent meaning to be attached to the language (Prawat, 1989). Cobb and colleagues (1992) asserted the role of “taken-as-shared” meaning on students’ interpretations of instructional materials. Although individuals differ in their construction of knowledge and have no direct access to each other’s understanding, negotiation of meaning (public knowledge) would allow individual construction of taken-as-shared meaning (Simon, 1995).
In general, the negotiation of meaning or discourse, which takes place during the public knowledge, might influence individual’s knowledge only when the individual carefully examines the new knowledge with respect to the existing one. Consequently, individual conceptual construction (conceptual framework) will undergo either a process of accommodation or assimilation depending upon the degree of changes needed.

*Constructivism and conceptual change model.*

A learner’s conceptual structure would undergo some restructuring or modification when attempting to integrate the new meaning of an experience with his/her previous conceptual structure. The degree of such modification relies on the meaning generated from the new experience. If the new meaning causes some dissatisfaction with the learner’s existing conceptual structure, disequilibrium would occur. To reconcile this and go back to an equilibrium situation, the learner might incorporate the new meaning into his or her conceptual structure; however, in case of enormous dissatisfaction, the learner has to modify or reconstruct his or her knowledge structure to reach equilibrium. The former process, using Piaget expressions, is known as assimilation while the latter is known as accommodation (Ginsburg & Opper, 1969).

Posner and colleagues (1982), taking into account the concept of human nature to adhering to one’s own knowledge, proposed four necessary criteria that the new knowledge must satisfy in order for accommodation to take place. Besides causing dissatisfaction with a specific existing knowledge, the new knowledge must be intelligible, plausible, and fruitful. That is, the new knowledge must be logical, appears compatible with other parts of the existing knowledge structure of the learner (solving previous problems), and indicates
possibilities of predicting solutions for other (new) problems (Posner et al., 1982). Thus, the main task of a teacher is to promote the intelligibility of a concept intelligible.

Intelligibility of the new knowledge, however, depends not only on the way the new concept is presented during classroom discourse, but also on the way the concept is presented mentally in mind of the learner. The learner’s ability to communicate a concept during a classroom discourse (external representation or public aspect of knowledge) reflects his or her mental representation (internal representation or the private aspect of knowledge) of the concept (Thorley & Stofflett, 1996). Plausibility of the concept, in turn, reflects the learner justification (reasoning) for the validity of his or her belief, which is derived from already constructed knowledge (Driver, Newton, & Osborne, 2000). Fruitfulness, on the other hand, stands for the motivation of the learner to struggle to understand, therefore, “to influence motivation to understand, a conception should be seen as fruitful by the learner” (Thorley & Stofflett, 1996, 322).

**Constructivist teaching model.**

Simon (1995), while developing a model for teaching mathematics using constructivist approaches, asserted that “constructivist epistemology does not determine the appropriateness or inappropriateness of teaching strategies” (p. 117). In his model, which can be adapted for teaching any other discipline, Simon suggested that the teacher’s knowledge of his/her discipline (teacher’ conceptual and pedagogical knowledge) and the teacher’s hypotheses of students’ prior knowledge would shape the design of a lesson/unit, which he labeled the hypothetical learning trajectory. The word “hypothesis” is used to indicate that the teacher has no direct access to students’ knowledge. The teacher’s hypothetical learning trajectory consists of three components: the learning goals, the learning
activities, and the hypothesis of the learning process. The use of the term "hypothetical" indicates that the learning path is not "fixed," which implies modifications or changes to any component of the path whenever necessary according to the actual learning context. Therefore, the teacher's pedagogical knowledge is continually developed.

When this model is adapted to science teaching, one must take into consideration that science knowledge is composed of two types of knowledge: declarative knowledge and procedural knowledge. While the former refers to the facts, principles, laws, and theories that constitute the knowledge base of the subject that is "learning that," the later refers to the process or the method involved in the construction of this knowledge. That is, learning "how and when" (Duschl, 1990). The traditional didactic teaching is approach usually focused on the declarative knowledge separated from the procedural knowledge.

Integrating the procedural knowledge and the declarative knowledge is very crucial to constructivists for three reasons. First, the constructivist teaching approach acknowledges the limitation of the language (speech) in conveying ideas and thoughts. Although language and thoughts are entwined, thoughts are viewed as a whole or holistic, while the language used to express any thought is partitioned into separate words (Vygotsky, 1987). Wells (1986) supports this description of the relationships between thoughts and language when he started "it is simply not possible to convey the ideas I have in mind in a form that does full justice to their simultaneous complexity and specificity" (1986, p. 215).

Second, procedural knowledge indicates that the context in which knowledge is developed is an integral part in the learning process. Tennyson and Cocchiarella (1986) stated that "concept may have one label, but several definitions, each dependent on specific context" (p. 61). Prawat (1990) clarified this notion in stating that
When a concept is used in a specific situation, it is recast, acquiring new meaning that it did not possess before . . . a good part of the meaning is inherited from the context of use. The situation, thus, becomes part of the meaning of the concept. (p. 30)

Finally, the context in which the meaning will develop stresses the public aspect of knowledge, in which negotiation of meaning is considered a primary instructional goal to promote students' understanding. Such a relationship between content and context would facilitate the taken-as-shared meaning among individuals involved in the meaning negotiation context. Therefore, the integration of declarative knowledge and procedural knowledge will facilitate the development of conceptual understanding of subject matter knowledge, as Hiebert and Carpenter (1992) suggested, “if the learner connects the procedure with some of the conceptual knowledge on which it is based, then the procedure becomes part of a larger network, closely related to conceptual knowledge” (p. 78). They further point out the importance of such connections in retrieving knowledge where the “procedures connected to networks [would] gain access to all information in the network” (Hiebert & Carpenter, 1992, p. 78).

The actual classroom interaction would have an impact on the teacher's knowledge, which in turn will affect his/her design of the lesson. Simon (1995) highlights such interaction in the model from teachers' perspective, labeling it as the mathematical teaching cycle (MTC) (Simon, 1995). In general, the teacher's knowledge of student knowledge is derived from the interaction with students and constitutes part of the teacher's knowledge that affects his/her pedagogical decision. Further, this knowledge, along with the teacher's conceptual knowledge of his/her discipline provides the basis for choosing goals for student learning. Nevertheless, the choice of student goals is not fixed; rather, it is always
undergoing modifications based on the teacher’s interaction with his/her students. The students’ goals will direct the planning of activities, which in turn depends on the teacher’s hypothetical learning path by which learning might occur.

As pointed out earlier, the planning of the hypothetical learning trajectory is subject to change at any time during the implementation phase, based on the actual classroom experience (interaction with students) that might be different from the one anticipated by teacher in the planning phase. A modification of the teacher’s ideas and knowledge will result as the teacher makes attempts to sense of what happens during the classroom interaction. In turn, a modification of the goals is necessary. Simon (1997) described the model as an inquiry process in which the teacher is involved in both building a model and generating a hypothesis, which implies that teaching is a continuous learning process.

Further, teachers’ beliefs have an essential role in teaching practice (Bryan, 2003; Haney, Czerniak, & Lumpe, 1996). Teachers’ belief and perceptions about their own role in classrooms, students’ learning and constructivist learning, and teaching theory could effect their implementation of constructivist teaching approaches. Consequently, it appeared that there are overlaps between the teachers’ hypothetical learning trajectory in MCT model and the teachers’ beliefs and perceptions for teaching and learning (Simon, 1995).

**Teacher roles.**

Simon (1995) asserted that “constructivism, as an epistemological theory, does not define a particular way of teaching” (p. 117). Yet, when using constructivist approaches, the teacher needs to avoid the “didactic approach” in favor of a “process approach” (Millar & Driver, 1987). Teaching should not be centered on a lecturing format where the aim is to cover the content because this teaching approach reflects the notion that knowledge can be
transferred. Also, students will be engaged more in exchanging performance for grades rather than being involved in understanding the knowledge (Wheatley, 1989).

Teaching using constructivist approaches (e.g. student-oriented) focus on conceptual understanding, which requires a different teacher role. Teachers need to perceive their role as scaffolding students' understanding of the concepts rather than transmitting concepts. Constructivist approaches suggests that teachers must have a robust understanding of the discipline's conceptual knowledge. Teachers need to know what ideas or concepts are considered most central to the discipline and how they are related to one another (Prawat, 1989). Teacher's conceptual knowledge is considered a central requirement for teachers when shifting toward a constructivist teaching pedagogy (Simon, 1995).

As stated above, constructivist educators view learning as an active process in which a learner should be involved in a process of constructing knowledge (Wheatley, 1989); therefore, teaching from this approach requires engaging the learner in “doing” knowledge rather than solely accumulating facts about knowledge. Consequently, teachers need to ensure that the concept to be learned is contextualized. This implies that teachers should inquire about students' prior knowledge and view them as an integral part of their strategies when shifting to the constructivist teaching pedagogy.

In addition to strong discipline knowledge, negotiation is another skill that teachers need to develop (Driver, 1990). Classroom negotiation, like dealing with public knowledge, can be seen as a process of “overcoming obstacles skillfully” (Prawat, 1989, p. 321). As indicated earlier, the main goal of initiating classroom negotiation is to reach agreement or “taken-as-shared” knowledge (Cobb et al., 1992). Negotiation enables a consistent meaning to be attached to the language used by those who were involved (Prawat, 1989).
To promote students' negotiation and agreement, teachers need to improve their questioning skills. Many educators emphasize teacher questioning as a means for a constructivist approach that supports student understanding (Penick, Crow & Bonnstetter, 1996). In order for the negotiation of meaning to be productive and effective in promoting student understanding, teachers need to be non-judgmental, enthusiastic, and energetic while using their questioning skills. Setting up a non-threatening learning environment enables the sharing of all participants’ views and ideas and also provides opportunities for reflecting on each others’ ideas. So, this type of learning environment promotes both aspects of knowledge: public and private. While students’ discussion of their ideas, in a non-threatening learning environment, promotes students’ cognition, such interaction mirrors the public aspect of knowledge. On the other hand, encouraging students to reflect on their ideas and evaluate how those ideas relate to other students’ ideas will function as a metacognition and enable the private aspect of knowledge.

In summary, constructivism as learning theory has many interpretations or faces that can be located on a continuum spectrum. Each face underlies different epistemological, psychological, pedagogical, and linguistic assumptions. Adopting this theory to science teaching context, however, required science teachers to follow different roles. The most important role is to promote opportunities for students to negotiate meaning.

**Argument**

Argument became to be known as a field of study that is derived from the integration of the study of logic and the study of human reasoning. While the former reflects the art of constructing correct inferences (conclusions) from given premises, the latter reflects the justifications from premises to conclusions in specific situations or contexts (Driver et al,
In an attempt to provide a useful definition of argument, Newton, Driver, and Osborne (1999) cited Krummheuer's (1995) definition of argument as "the intentional explication of the reasoning of a solution during its development or after it" (p.231). According to this framework, argument can take place in isolation or in social context.

When, on one hand, an individual attempts to explain his or her reasoning through a single line of thought as in an essay or lecture, such individual activity might be known as analytical argument (van Eemeren et al., 1996), monological argument (Newton et al., 1999), rhetorical argument (Kuhn, 1992), or didactic argument (Boulter & Gilbert, 1995). On the other hand, if a number of people are involved in sharing their reasoning explications where some different views are to be examined, then dialectical argument (van Eemeren et al., 1996), dialogical argument (Driver et al., 2000; Newton et al., 1999), or multivoiced argument (Driver et al., 2000) reflects their social activity.

Within the last few decades, research in the field of science education has began to focus on using argumentation in science classrooms as a mean of coordinating evidence to either support or refute an explanatory conclusion, model, or prediction (Suppe, 1998). The foundation of argumentation theory goes back to Toulmin (1958), who used the theory of logic to analyze several arguments from different context and managed to identify four important components: claims, which are statements reflecting conclusions or assertions for the knowledge to be established; grounds or data, which stand for a set of observations, facts, and/or results that are aimed to support the claim; warrants, reasons aimed to justify the connection between the particular data and the claims or conclusions; backings, basic assumptions, which are commonly agreed upon, to provide justification for particular warrant.
Toulmin's model was based on analysis of arguments in a decontextualized manner (e.g. written arguments), where no recognition is given to the discourse phenomenon that is influenced by the linguistic and situational contexts in which the specific argument is embedded (Driver et al., 2000). This is a critical point, especially when considering the use of arguments in classrooms, because, as stated earlier, the targeted concept to be learned must be attached to a context in which its meaning is inferred as sometimes the same statement may have a different meaning in a different context (Thorley & Stofflettt, 1996).

Another reason for why context should be considered in dialogic argument is the importance of the use of gestures, such as pointing at objects and nodding. Usually people tend to finish a sentence using gestures or nonverbal expressions (Atwater, 1996). Finally, the social relationships within the members of the group developing the argument are important to consider, for example, a sharing "the floor" relationship instead of a power relationship between teachers and the students. Evaluating or constructing a meaning from a group discussion is considered as a product of both cognitive and social factors (Richmond & Striley, 1996). Billings and Fitzgerald (2002) argued that argumentation and context cannot be separated:

Language, and literacy, meanings and understandings are inseparable from cultural and social contexts in which they occur. . . . Reciprocal flow of ideas involving actions and reactions of group members may lead to new understandings not held by any group member in advance of the discussion. (p. 909)

Theories for argument have been developed based on where the emphasis is placed. Some have focused on defining criteria and procedural analysis for the construction of argument, for example, Kuhn (1993) defined a framework when conducting dialogical
argument about social issues based on the ability of describing and justifying models, presenting alternative theories, presenting counterargument, and providing rebuttals. Others have focused on providing analysis of practiced argument, for example, Blair and Johnson (1987) identified three criteria that the premises of an argument must satisfy: relevance, sufficiency, and acceptability. Relevance stands for the relationship between the contents of the premises and the claim. While sufficiency answers the question, does the premise provide enough evidence for the claim?, acceptability questions the relativity of the premise, that is, are premises true, probable, or reliable? Involvement in an argument, however, requires building certain skills of recognizing, composing, and evaluating. Therefore, in educational settings, “it is necessary to pay attention not only to the ways in which students understand the argument process, but also to the social skills necessary for conducting arguments in group” (Driver et al., 2000, p. 295).

**Argument and Constructivism**

As indicated earlier, constructivism as an epistemological theory distinguishes between the existence of the true reality (the natural world) and our knowledge about it. While the former exists independent of the knower, the latter does not. Yet, truth is also independent of context in which it may be generated. Constructivism, therefore, acknowledges that scientific knowledge is a human construction, built (and still being built) based on centuries of human endeavors. Thus, two crucial questions faced the scientific knowledge enterprise: what and how do scientists know?

These two fundamental questions suggest to constructivist science educators that science learning should not mainly be about knowing concepts, ideas, and theories, which scientists have already accumulated and developed about the world (know the what question)
or about knowing how to design, conduct an experiment, and controlling variables (know the how question). Rather, learning science should also encompass an appreciation of the role of evidence and recognition of the social interaction (argument) in contributing to the scientific enterprise. While some disputes can take years to be resolved, resolution, in some cases, is never achieved (Kuhn, 1970).

Scientific experiments and observations, therefore, are not the sole basis upon which science knowledge is built. Yet, experiments and observations serve to support the knowledge claims through the rational activity of generating arguments. Thus, science knowledge is built upon the strength of the argument and its supporting evidence, upon which scientists judge the competing knowledge claims and work out whether to accept or reject them (Driver et al., 2000).

*Argument in Science Education*

The current practice of science teaching has paid little attention to the inclusion of argumentation and controversy in science teaching strategies. This omission has created a false notion of learning science as a collection of facts about the world and also has “failed to empower students with the ability to argue scientifically” regarding “socio-scientific issues” that they would encounter in their everyday lives (Newton et al., 1999, p. 556). Therefore, “if pupils are genuinely to understand scientific practice, and if they are to become equipped with the ability to think scientifically through everyday issues, then argumentative practices will need to be a feature of their education in science” (Newton et al., 1999, p. 556).

The shift toward student-oriented approaches led to the emphasis on student talking and discussion as meaning-making strategies designed to enable students’ understanding of scientific ideas. Hodson and Hodson (1998), building on Vygotsky’s sociocultural theory,
argued that “teaching comprises the activities associated with enabling the learner to participate effectively in the activities of the more expert, and learning is seen as enculturation via guided and modeled participation” (p. 37). The enculturation process of learning science could be accomplished through actual practice. Driver and colleagues (2000) have emphasized the significant role of practice via providing an analogy with learning a second language: “this process of enculturation into science comes about in a very similar way to the way a foreign language is learned — through its use” (p. 298). Teachers, therefore, need to facilitate more learning opportunities by creating authenticated contexts for students to practice using science ideas to become more confident in their use and, not only develop familiarity with the science language, but also to understand the ideas of science (Atwater, 1996; Driver et al., 2000; Hodson & Hodson, 1998; Jiménez-Aleixander, Rodríguez & Duschl, 2000; Newton et al., 1999; Simon, Erduran & Osborne, 2002; Zohar & Nemet, 2002).

Lonning (1993) asserted that learning through classroom interaction will improve student verbal interaction. Hand, Treagust, and Vance (1997) further argued that learning science through argumentation and interaction with peers, either in small or large groups, might cause students to change their ideas about the absolute truth of scientific concepts and to perceive such interaction as an important process to reach consensus regarding scientific concepts and ideas. Yerrick (2000) when studying the effect of using argument on low-ability science achievement asserted that learning science through argument revealed a shift in low-ability student understanding of the tentative nature of science reflected from their reasoning and negotiation of knowledge claims and evidence.

The importance of classroom negotiation originated from two perspectives: the learner’s prior knowledge and the usage of the scientific language. Through argument,
students use their own language to explain the meaning of scientific concepts or ideas. Further, they will provide reasons to justify their meanings, for example, argument conducted after laboratory investigations, and sometimes students support their reasoning with some collected results. Yet, such reasoning (warrants) are based on prior knowledge and, in turn, serves not only as an indicators for students' prior knowledge but also as an evaluation of conceptual understanding. Hand, Hohenshell, and Prain (2004) suggested that non-didactic tasks in science classrooms promote opportunities for students to organize their thoughts through reflection and clarification of the used language, which in turn enhance their understanding.

In summary, the emphasis placed on constructivist learning has led to a shift in pedagogical practice from teacher-oriented to student-oriented. Thus, encompassing dialogical argument in science classrooms is crucial to both understanding science concepts and promoting students' reasoning. Teachers need to scaffold students' discussion by promoting more opportunities for them to talk, reflect, and reason about their ideas in a non-teacher dominated discussion. Further, the process of discussion upon which students solve scientific problems within a conceptual area requires practical investigation, which in turn places more demands on the type of inquiry (experimentation) teachers implement in science classrooms.

**Writing in Science**

The enculturation process of learning science encompasses writing as a means to communicate science ideas to different audiences and as a unidirectional way of conducting written argument. Holliday, Yore and Alvermann (1994) argued that the goals of students using writing tasks should encompass “solving communication problems, informing or
persuading others [besides] constructing understanding” (p. 885). Rivard (1994), in his review, identified several crucial elements within writing that can enhance learning including the demands of the writing tasks placed on the learner’s, the learner metacognitive understanding of the appropriate strategy to apply, and a classroom environment that promotes student interaction and a focus on deeper conceptual understanding rather than the transmitting of content.

Although, during the last decade, several educators have emphasized the importance of using writing to enhance science learning (Keys, 1999; 2000; Prain & Hand, 1996 a; Sutton, 1993; Yore, Bisanz, & Hand, 2003), various emphases have been placed on the writing genre to be used based on the intended purpose. For instance, educators who support using traditional (formal) writing in science (e.g. reports, articles, etc.) argue that students need to use proper technical scientific language (Halliday & Martin, 1993). Hand and Prain (2002) explained that advocates of the traditional writing genre in science view writing-to-learn as “the process whereby students learn about the functions of particular micro and macro linguistic features in traditional forms of science writing, such as the laboratory or research report” (p. 741). They further pointed to the following intended goals from such approaches:

- to give learners access to the assumptions, procedures, “hidden” rules, and purposes of scientific writing as the basis for understanding what counts as scientific method, explanation, and justification, as well as the underlying history and rationale of this writing as practice. (Hand & Prain, 2002, p. 741)

Advocates of the traditional writing genres distinguish between scientific terminology and everyday language and place more emphasis on knowing and using the subject-specific
vocabulary (Martin and Veel, 1998). Learning is viewed as the acquisition of such generic knowledge and the ability to interpret, reproduce and use that knowledge in a meaningful context (Hand and Prain, 2002).

Prain and Hand (1996), in arguing for the opposite view, the nontraditional (informal or expressive) writing genre, argued that students should be encouraged to write about their understanding of science concepts in a variety of ways using their own language to enhance their learning. Learning occurs as students strive to articulate or “translate” their understanding in a variety of genres (Gunstone, 1995). Furthermore, Hand and Prain (2002) postulated that learning occurs as “students engage successfully with the demands of communicating to actual readerships, including themselves, for meaningful and varied purposes” (p. 742).

Langer and Applebee (1987) in their review of the studies that implemented writing in science classrooms during the 1970s and 1980s concluded that teachers use writing for evaluation purposes, such as situations when students write short informational passages to respond to the given writing task (essays or short-answer questions). Students mechanically use a knowledge-telling writing model to accomplish the task in which they recall (retrieve) related ideas or concepts, draft a text, and proofread the draft to produce the final copy (Yore, Bisanz & Hand, 2003). In turn, teachers interpret student writing either to assess student understanding and consolidation of new ideas or to inquire about relative knowledge when preparing for the new unit or activity.

Hand and Prain (2002) pointed to the demands of changing the learning environment to advocate the implementation of effective writing-to-learn in science, which should be accompanied with changes in a teacher’s beliefs, concerns, and practice. Hand, Prain,
Lawrence and Yore (1999) highlighted effective conditions for using writing-to-learn in science compatible with the interactive constructivist approach, which encompasses the evaluativist view of science: an inquiry-driven learning environment and "two-way communication" to negotiate meaning. They argue that writing in an interactive constructivist science classroom would enhance student learning through consolidating three activities: developing reasoning, practicing argument, and constructing meaning (Hand et al., 1999).

Prain and Hand (1996 b) proposed a model for using non traditional writing-to-learn to guide science teachers in the planning of writing tasks. They identified five crucial elements for the model to illustrate the complexity of connections between the demands of different writing tasks and types, subject-topic-task interactions, and student learning outcomes (Hand & Prain, 2002; Prain & Hand, 1996 b). Theses elements are audience, purpose, writing types, methods of text production, and writing topics. Each element includes several dimensions, which provide teachers with multiple combinations of writing tasks. Teachers need to develop their understanding of the subject matter and develop an understanding of task requirements from "a theoretical viewpoint and a pragmatic pedagogical perspective" in order to effectively implement writing-to-learn (Hand & Prain, 2002, p. 744).

The Science Writing Heuristic

Keys (1999) argued that, teachers should implement both types of writing whether it is formal or informal to reinforce science learning, so that students can benefit from using a modified version of the traditional laboratory report genre that attaches more meaning to their writing and encourages them to elaborate on their understanding through providing
explicit reasoning for their knowledge claims. She argued that, even if using writing in science classrooms would not increase science understanding, it would, at least, increase learner technical writing performance.

Hand and Keys (1999), as an attempt to develop a rich teaching/learning approach using these ideas, constructed the science writing heuristic (SWH), which they consider to be an inquiry-based approach that links writing, reading, and science laboratory activities. The framework for designing the SWH includes the shift to constructivist theory, understanding the nature of science, and promoting scientific literacy. The SWH consists of two templates one for the teacher and the other for student.

The teacher template (Figure 1) provides important phases of suggested activities to enhance learning by promoting negotiation of meaning among students and/or among students and teachers in both small- and large-group activities. These processes of negotiating meaning are essential to allow students to construct, filter, and modify their science conception. Thus, the teacher template provides strong pedagogical focus for implementing and conducting scientific investigation as a means to learn the scientific methods and procedures (Keys, Hand, Prain, & Collins, 1999).

- Exploration of pre-instruction understanding
- Pre-laboratory activities
- Laboratory activity
- Negotiation- individual writing
- Negotiation- group discussion
- Negotiation- textbook and other resources
- Negotiation- individual writing
- Exploration of post-instruction understanding

Figure 1. A template for teacher-designed activities to promote laboratory understanding
Initially, the teacher needs to build upon his or her students’ background knowledge to be able to invite them to a discussion after allowing time to formulate their own questions about the targeted concepts or ideas within the framework provided. Such activity enables students to distinguish questions that are researchable from other questions and learn about issues related to the nature of science. The discussion should also deal with procedural investigation. Such discussion is also valuable in helping students to understanding their abilities at problem solving (general metacognitive knowledge) and their prior knowledge related to the concepts (domain-specific metacognitive knowledge, Kramarski & Mevarech, 2003). Further, providing this opportunity for students to create their own investigating procedure enables them to predict or anticipated results and think of how to relate them to the question being asked.

The teacher template also includes small group negotiation phases in which the teacher initiates dialogical interaction with students while they are investigating so as to draw their attention to the data collected from the activity and how to interpret them. In doing this, students would discuss observations and other data with their peers and generate a knowledge claim. A large group negotiation of the knowledge claims and the supporting evidence will enable students to refine or alter their knowledge claim according to the evidence (reasoning) provided to support them. Students were all negotiating phases to write their laboratory (activity) report and consult the knowledge claimed with authoritative texts (Hand & Keys, 1999).

On the other hand, the student template (Figure 2) is to scaffold student understanding of scientific concepts while writing the laboratory report by relating claims to evidence (Hand & Keys, 1999). The heuristic is constructed upon an epistemological view that allows
students to think about their claims and how they might interpret the data to provide supporting evidence. The SWH is based on the assumption that science writing genres in school should reflect some of the characteristics of scientist’s writing and be shaped as a pedagogical tool that encourages students to distinguish scientific meaning from reasoning. A comparison of the components of the SWH student template to the traditional laboratory report template illustrates the differences among the two templates (figure 3).

- Beginning questions or ideas
  What are my questions about this experiment?
- Tests and Procedures
  What will I do to help answer my questions?
- Observations
  What did I see when I completed my tests and procedure?
- Claims
  What can I claim?
- Evidence
  What evidence do I have to support my claim? How do I know? Why am I making these claims?
- Reading
  How do my ideas compare with others?
- Reflection
  How have my ideas changed?

**Figure 2. The SWH, a template for student thinking**

<table>
<thead>
<tr>
<th>The SWH format</th>
<th>The traditional format</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beginning questions or ideas</td>
<td>Title, purpose</td>
</tr>
<tr>
<td>Tests and procedures</td>
<td>Outline of procedure</td>
</tr>
<tr>
<td>Observations</td>
<td>Data and observations</td>
</tr>
<tr>
<td>Claims</td>
<td>Discussion</td>
</tr>
<tr>
<td>Evidence</td>
<td>Balanced equations, calculations, graphs</td>
</tr>
<tr>
<td>Reflection</td>
<td>No Equivalent</td>
</tr>
</tbody>
</table>

**Figure 3. Comparison of the SWH format to the traditional format**
Thus, the SWH is conceptualized as a vehicle to illuminate the construction and testing of explanations of evidence drawn from science laboratory activities. Further, several studies show that the implementation of the SWH has promoted students metacognition by inviting them to reflect on their knowledge, abilities to generate meaning from data, abilities to extend science ideas, and understanding the nature of science (Hand, Hohenshell, & Prain, 2004; Hand, Prain, & Hohenshell, 2001; Keys et al., 1999).

**The SWH as an inquiry teaching.**

The National science education standards (NRC, 1996) strongly advocate the inclusion of inquiry-base science instruction in which students become involved in identifying researchable questions, designing and conducting experiments, developing explanations, thinking critically about the relationship between evidence and explanations, and communicating scientific procedures and explanations. Yet, up to date science teachers struggle to implement inquiry-based instructional science classrooms as recommended by the standards (NSES, 1996). The inquiry activities that teachers usually implemented have predetermined procedures and known outcomes. Although such types of inquiry promote some student activities, such as observing, measuring, and collecting data, they do not scaffold student’s higher level thinking and reasoning, and in fact, are generally not considered inquiry (Eick & Reed, 2002).

The main goal beyond implementation of inquiry in classrooms is to promote authentic contexts for students to learn and practice the art of reasoning. This requires teachers to be prepared with knowledge and skills to scaffold their students thinking through the inquiry investigation. On the other hand, the promotion of authenticated science
classroom learning environments will impact students' perception, attitudes, and beliefs of science (Jones, Howe & Rua, 2000; Riesz et al., 1994; Mason & Kahle, 1988), which in turn influence students' choice to be enrolled in science courses with respect to their gender (Keeves & Kotte, 1992). Keeves and Kotte (1992) highlighted the gender difference in science courses enrollment and achievement. While male students are enrolled more in physical science courses (physics and chemistry) and outperformed the female students, female students are enrolled more in biology course with no achievement difference. Jones, Howe and Rua (2000) argued that the early experiences of science are crucial to robust understanding of scientific concepts. They asserted that the gender difference in science achievement was widened starting from middle school levels.

Results drawn from a recent study (Poock, Burke, Greenbowe, Hand, 2004) that used the SWH in a chemistry course for tertiary level provided evidence of closing the gap in gender achievement level measured from students' responses to American Chemical Society California Diagnostic Exam at the end of the semester; while the difference in gender improvement scores was significant in the beginning of the semester, the difference was not significant at the end of the semester with females scoring larger improvement score ($F=0.26$) than male ($M=0.16$).

Secker and Lissitz (1999) found that instructional strategies affected students' achievement in science; while using authenticated inquiry and student-oriented approaches reflected by the dialogical interactions closed the gender gap, teacher-oriented instruction approaches reflected of the didactic instructions widened the gender gap. Following are four types of inquiry—as practiced in science classrooms—classified on a continuum spectrum based on the control exerted by teacher and students with respect to the knowledge or
concept discussed. Beginning with teacher total control at one end, the type of inquiry practiced reflects information confirmation in which students are involved in a given procedure to verify knowledge already presented (Windschitl, 2003). In structured inquiry the teacher provides the question and procedure for the investigation; yet, students do not know the answer for the question in advance. Guided inquiry is a higher level of inquiry in which students are given only the question to investigate not the procedure. The highest level of inquiry is independent inquiry in which students generate their own questions of the problem and design their own procedure to investigate (Chinn & Malhorta, 2002; Windschitl, 2003).

Although the difference seems trivial between each two consecutive types of inquiry, students' cognitive actions are intellectually challenged when moving toward open inquiry. For instance, allowing students to design their own investigating procedure, as in guided inquiry, motivates their creativity, their scientific knowledge related to the problem, and their investigation skills. In open inquiry, giving students the opportunity to ask their own questions to inquire about within a specific concept or framework idea, on the other hand, is more cognitively challenging for the students; students have to create a researchable question and design a procedural to collect data that they believe will help answering the question. Further, both types of inquiry are promoting opportunities for students to perceive how evidence supports the knowledge claim.

From this perspective, the SWH as an inquiry tool suggests several activities that science teachers need to promote in their classrooms. Teachers need to promote opportunities for their students to argue for their knowledge claim providing supporting reasoning not only in written format which mainly promotes the private aspect of knowledge, but also in social
setting through inviting students to participate in discussion and argument of the knowledge claimed to promote the public aspect of knowledge as well.

**Professional Development**

In the traditional teaching approach, science teachers usually present science as an accumulation of facts, theories, and rules that students have to memorize and practice. This approach has resulted in poor understanding of scientific concepts, decreasing popularity of science, and declining numbers of students choosing science subjects as a specialization (Millar & Osborne, 1998). Several publications that called for science curriculum reform focus on inquiry as the central element to promote both students’ understanding of scientific concepts and the development of their reasoning skills (AAAS, 1993, NRC, 1996, NSES, 1996). Teachers must design their science lessons in an active way, so that both the phrases “hands on” and “minds on” reflect the core of their educational practice (van Driel, Beijaard & Verloop, 2001). In other words, science teaching should be shifted towards implementing more constructivist pedagogical approaches, in which the traditional didactic approaches that defined the role of the both the teacher and the learner is replaced by more dialogical interactive approaches that put the student at the center of the educational enterprise.

Science teachers struggle to implement such a complex approach due to their poor understanding of constructivism as a theory and the foundations of its educational practice (Luft, 2001; Osborne & Wellington, 2001; Windschitl, 2002). However, possessing a deeper understanding of the theory and sufficient knowledge of its underpinning principles is not enough unless the teachers are willing to question and transform their understanding of teaching and learning concepts. Therefore, any inservice program aiming at shifting and/or improving science teachers practice should focus on teachers’ epistemology.
Windschitl (2002) argued that teacher's "epistemology must become an explicit target of change. Without such change as a priority, efforts directed at teacher development become narrowly focused on changing the kinds of attributes and skills that may be added to, subtracted from, or modified" (p. 143). Haney, Czerniak and Lumpe (1996) highlighted a similar idea earlier in their study asserting that educational reform efforts are doomed to fail if the emphasis is placed on developing specific teacher skills, unless the teachers' cognitions and beliefs are taken into account. If they are not taken into account, any change would be hindered if teachers believe that teaching is equivalent to a transmissive practice. Therefore, efforts to help teachers understand and implement the constructivist approach should not reflect merely additive skills; rather, such efforts should foster fundamental changes to beliefs, knowledge, and habits of practice that teachers deeply hold. O'Brien (1992), in a meta-analysis of inservice professional development programs, asserted that learning about the theory and concepts underlying the instruction are critical. Both theory and concepts provide science teachers with information to support their use and understanding of the constructivist instructional approach. Therefore, professional development programs need to pay attention to teacher beliefs which interact with their practices (Richardson, 1990).

Cronin-Jones (1991) defined categories of teachers' beliefs that might hinder any inservice professional development program. Among these categories are the teachers' beliefs about their own role in classrooms, which could effect their implementation of any constructivist approach intended by an inservice program. For example, during the implementation of interactive dialogic discussion strategies, teachers who view their roles as the center of classrooms will control the discussion by deciding who will talk, when a person can talk and will provide their final evaluation or judgment about the ideas under discussion.
In other words, their beliefs about their role will prevent transformation to the necessary pedagogical practices for implementing constructivist approaches.

Another belief that might influence any inservice professional development program is teachers' beliefs about the way their students learn (Cronin-Jones, 1991). According to Simon’s model (1995), teachers’ hypothetical ideas about how learning occurs constitute a crucial element when implementing constructivist approaches. Carpenter, Fennema and Franke (1996), based on a study using the cognitively guided instruction model within inservice mathematical teacher professional development program, argued that teachers’ understanding of student thinking allowed them to make instructional decisions.

**Levels of Changes as Professional Growth**

Franke, Carpenter, Fennema, Ansell and Behrend (1998) argued that in order for any inservice programs to become effective and generative “teachers must begin to engage in practices that have built-in support for the changes they have made; otherwise, the changes are likely to erode over time” (p. 67). For example, teachers should experience the benefit of using classroom dialogic discussion in generating meanings, scaffolding students’ understanding of scientific concepts, and promoting a higher level of thinking to continue applying and favoring such dialogic approaches over the didactic one. Nevertheless, enough time is needed to fully adopt and understand the underpinning theory beyond the new teaching approach. Fullan (1982) asserted this point in stating It is possible to change the “on the surface” by endorsing certain goals, using specific materials and even imitating the behaviour without specifically understanding the principles and rationale of the change. Moreover, in reference to beliefs, it is possible to value and be
articulate about the goals of the change without understanding their implications for practice.

(p. 35)

During the implementation of a new theoretical teaching approach, each teacher will begin to develop his/her understanding of the new approach based on the interaction between practice and theory. Therefore, when implementing a new teaching approach, teachers need enough time to try the new approach, practice the necessary pedagogical skills, and discuss the results obtained to allow for the construction of new knowledge underpinning the new approach (van Driel, Beijaard and Verloop, 2001).

Research focusing on teacher professional development has identified different stages of concern that teachers struggle with when implementing a new teaching approach. The concept that teachers’ professional development evolves gradually through several stages attracted several educators. For example, James and Hall (1981) highlighted seven stages of teacher concern: awareness, informational, personal, management, consequence, collaboration and refocusing. Further, they report, based on survey results, that teachers have concerns about all seven stages at the same time; yet, during the implementation process, a specific concern, according to the level of teacher interest, overcomes the others. Simon and Schifter (1987) also identified similar stages of professional development. These include lacking the epistemological constructivist knowledge, focusing on implementation of skills (teaching behaviors) required for constructivist approaches, and focusing on the learner, which reflects more confidence in teaching skills.

Hand (1996), considering teachers as learners and building on the conceptual change model of Posner and colleagues (1982), suggested a model for professional development that includes five sequential stages of teacher developmental when implementing constructivist
teaching approaches. These stages include identification of teacher's knowledge of classroom practice, teacher's identification of students' knowledge of science, teacher's knowledge of own pedagogy and science concept knowledge, teacher's application and linking science concepts and pedagogical knowledge, and development of a constructivist teaching framework.

Within the last decade, mathematics educators shifted the focus of professional development programs from merely applying new teaching approaches to a wider focus of causing generative changes within teacher practice (Carpenter et al., 1996; Franke et al., 1998). While applying cognitively guided inquiry (CGI) as an inservice mathematical teachers' professional development program, they analyzed teachers' cognitive thinking with respect to their understanding of students' thinking. Carpenter and colleagues (1996) argued that “understanding students’ mathematical thinking can provide a unifying framework for the development of teachers’ knowledge” (p. 4). They further concluded that “teachers’ thinking about pedagogy is refocused so that the primary considerations revolve around student thinking rather than teacher actions” (Carpenter et al., 1996, p. 16).

Franke and colleagues (2001) conducted a follow-up study by observing and interviewing the teachers, who participated in the CGI inservice program four years earlier. They define four levels—with two embedded layers within the fourth level—of teachers' generative growth based on their beliefs about their students' thinking (Franke, Carpenter, Levi & Fennema, 2001).

In summary, several educational professional development programs have been proposed and carried out to support inservice science and math teacher implementation of a new teaching approach. All professional development programs are similar in proposing
constructivist teaching approach to facilitate student construction of knowledge. A common assertion would be that, teachers’ implementations of new constructivist teaching approach reflect different levels of teacher professional development, which is expected because each teacher will differ in his or her interpretation of the new teaching approach due to the different interaction between each teacher practice and his or her belief.

Summary

This chapter has addressed the theoretical framework used to guide this study. The sections addressed as part of the framework include constructivism, argument, writing in science, and professional development. The field of science education has reflected great progress within the research of effective science teaching. Lately, science educators have been calling for teaching science through promoting argument in science classroom. The underpinning assumption of argument was discussed from the perspective of constructivist learning theory. The underpinning theory of the science writing heuristic (SWH) was discussed as an inquiry-based tool to help science teacher promote dialogical interaction. Finally, professional development programs were illustrated to assure that science teacher implementation of any new instructional approach would vary according to each teacher practice and belief.
CHAPTER THREE

Research Method

This chapter outlines the procedure used for the study and the rationale to justify the choice for the procedure and the data collecting techniques; therefore, the chapter is organized as follows: 1) overall research framework, including research validity and reliability, is presented to justify the approaches used in this study; 2) qualitative research design with data collection methods including three techniques used—observation, questionnaire, and interview—is detailed; 3) criteria for teacher level of implementation and the ranking mechanism are explained; 4) general overview of participating teachers from each school district and detailed information of the professional development program are illustrate and; 5) finally, the quantitative research design including validity and statistical analysis is explained.

This study examined the link between teachers’ implementation of a student-oriented approach and the shift within their teaching practices. Specifically, this study focused on teachers’ implementation of the pedagogical strategies recommended by the SWH as described in the literature review chapter. Further attention was devoted to the change in teachers’ thinking associated with their teaching practices when adopting the SWH as an interactive constructivist teaching/learning approach.

The overall approach of this study was to help inservice science teachers adopt and effectively apply the SWH approach within a professional development program. This study was part of a three-year longitudinal project—the SWH partnership project—conducted collaboratively with Iowa Department of Education to improve science teaching in Iowa. During the first year, 18 teachers from seven school districts participated in the study.
**Research Framework**

To ensure that generalizations can be constructed out of this study, a number of different procedures were adopted, each of which reinforced both internal and external validity. In this study, a mixed research approach (qualitative and quantitative) was applied. Fraser and Tobin (1992) asserted that both qualitative and quantitative data will add to the richness of the data as a whole in which “greater creditability [can] be placed in [the] findings because they emerge consistently from data obtained [by] using a range of different data collection methods” (p. 33). Tripp-Reimer (1985) highlighted such aspects of research methods by stating that

They [qualitative and quantitative methods] may provide complementary data, which together give a more complete picture than can be obtained using either method singly. Each has advantages and limitations: when fused together, the positive aspects of both may be seen. (p. 179)

Denzin (1988) further asserted that, “no single research method will ever capture all of the changing features of the social world under study” (p. 512). Thus, a mixed method approach was adopted for this study to add more robustness to the results generated from the study and to ensure generalization.

**Research Validity**

Validity for a qualitative approach differs from validity for a quantitative approach. While the latter reflects the degree to which an explanation of the phenomenon under the investigation matches the reality of the world, the former reflects “the degree to which the interpretations and concepts have mutual meanings between the participants and the researcher” (McMillan & Schumacher, 1997, p. 404). Yet, the crucial question of validity for
both approaches remains the same—that is, to what extent can the researcher trust the findings of a study? Guba and Lincoln (1981) asserted that,

It is difficult to talk about the validity and reliability of an experiment as a whole, but one can talk about the validity and reliability of the instrumentation, the appropriateness of the data analysis techniques, the degree of relationship between the conclusions drawn and the data upon which they presumably rest, and so on. (p. 378)

The issue dealing with research findings—answering the question of how findings match reality—is defined as internal validity (McMillan & Schumacher, 1997; Merriam, 1988).

Ratcliffe (1983) emphasized that, “data do not speak for themselves; there is always an interpreter or a translator” (p. 149), and numbers or words “are abstract, symbolic representations of reality, but not reality itself” (p. 150). According to Lincoln and Guba (1985), who defined reality as “a multiple set of mental constructions … made by humans” (p. 295), judging internal validity of a study depends on representing those multiple constructions adequately in a way that reveals the investigator’s perspective or philosophical view of the world—that is, the findings and interpretations are also derived through inquiry. Thus, the researcher’s view of the world not only affects inquires about the measuring instruments used for data gathering, but also limits them (Esterberg, 2002; Lincoln & Guba, 1985). Merriam (1988) further emphasized the importance of the philosophical approach adopted by a researcher when explaining data gathering methods, including data organization and interpretation. These methods not only affect internal validity, but also affect the generalizability of findings or the external validity, which deals with applicability of the finding to another context or situation; “validity, then, must be assessed in terms of
interpreting the investigator’s experience, rather than in terms of reality itself (which can never be grasped)” (Merriam, 1988, p. 167).

Researchers, in addition to defining two types of research validity, have also suggested strategies to enhance the validity of the research (Esterberg, 2002; Lincoln & Guba, 1985). Merriam (1988), for example, argued that a researcher should adopt strategies such as triangulation, long-term observation of a phenomenon, member checks, and/or peer examination to account for internal validity of a study. This study employed three of these strategies to ensure internal validity: triangulation, long-term observation, and member checks.

Triangulation can be defined as a method-appropriate strategy of founding the credibility of qualitative analyses (Denzin, 1988). Four types of triangulation have been defined: data triangulation, method triangulation, investigator (observer) triangulation, and theory triangulation. For the qualitative study, the researcher used multiple data collecting method, such as observation, questionnaire, and interview. However, data gathered from different sources might not be compatible. Mathison (1988) argued that such inconsistency or contradictory data actually promote more holistic understanding of the situation and enable the construction of “plausible explanations about phenomena being studied” (p. 17).

Long-term observation at the research site refers to multiple or repeated observations over a period of time. The existence of the researcher in the scenery of the investigation might affect the activity being observed. A trust relationship between observers and respondents is considered a crucial element to capturing real human behavior in the phenomenon under investigation (Gotez & LeCompte, 1984).
Member checks increase research validity by providing more support to the results generated from the study. Member checks or peer reviews imply seeking others’ views about the interpretation of the data or the results generated. Merriam (1988) and Esterberg (2002) suggested that taking the data or interpretation back to respondents or people from whom the data generated to seek plausibility is considered a type of member check. Lincoln and Guba (1985) insisted that such checking, informal and/or formal, should occur continuously to increase the creditability of research findings.

**Research Reliability**

Reliability is defined as “the consistency of measurement—the extent to which the results are similar over different forms of the same instrument or occasions of data collecting” (McMillan & Schumacher, 1997, p. 239). The assumption of reliability is that “there is a single reality which if studied repeatedly will give the same results” (Merriam, 1988, p. 170). Such as assumption differs for a qualitative research approach; hence the goal of qualitative research is not to “isolate laws of human behavior. Rather, it seeks to describe and explain the world as those in the world interpret it” (Merriam, 1988, p. 170). That is, interpretative qualitative research relay on the researcher’s attempt to explain human behavior, which in turn affect the consistency of the measurement.

Guba and Lincoln (1981) argued for marginalizing reliability in favor of internal validity when conducting qualitative research, “since it is impossible to have internal validity without reliability, a demonstration of internal validity amounts to a simultaneous demonstration of reliability” (p. 120). For consistency of results, recognition must be given to the need for identical data collection, situational context, and interpretation of results to be achieved.
Some of the techniques that might be used to insure reliability are triangulation in terms of using different methods for collecting data; audit trail (Merriam, 1988), or inter-rater-reliability (McMillan & Schumacher, 1997), in terms of obtaining independent judges to authenticate the findings; and a fully defined researcher position, assumption, and theory behind the study (Merriam, 1988).

**Qualitative Research Design**

The selection of a particular design such as an experimental design or nonexperimental design is determined by the research problem, the questions raised, and "the type of end product desired" (Merriam, 1988, p. 6), whether the results will be presented as a cause-and-effect relationship or as a holistic, intensive description and interpretation of a contemporary phenomenon. When determining the cause-and-effect relationship in educational research, it is not possible to have a true experimental study in which the researcher has complete control of all variables; therefore, quasi-experimental design is applied instead where "control is maintained to the extent possible and randomization is approximated through statistical and other procedures" (Merriam, 1988, p. 7).

On the other hand, educational researchers might select a nonexperimental design or, as widely known, descriptive if the research goal is to examine events or phenomena. McMillan and Schumacher (1997) highlighted this point by stating that, "the purpose of most descriptive research is limited to characterizing something as it is, though some descriptive research suggests tentative causal relationships. There is no manipulation of treatments or subjects; the researcher takes things as they are" (p. 26).

Case study is a form of descriptive, nonexperimental research method in which results are displayed in words rather than in numbers. In addition to the above-mentioned
three factors (the research problem, the questions raised, and the type of end product desired) that affect the selection of a study design, case studies are usually selected in educational research when investigating a bounded system, such as an event, a person, a process, a program, or a social group. Guba and Lincoln (1981) asserted that the purpose of applying a case study design is to uncover "the properties of the class to which the instance being studied belongs" (p. 371). According to Becker (1968), there are two rationales beyond selecting case study as a research design: to reach comprehensive understanding of the phenomenon under investigation and "to develop general theoretical statements about regularities in social structure and process" (Becker, 1968, p. 233). Thus, an essential property of a case study is particularistic (Wilson, 1979).

The particularistic property indicates that, "case studies focus on a particular situation, event, program, or phenomenon" (Merriam, 1988, p. 11). For example, in an educational setting, case studies may concentrate attention on the teaching practice of a particular group of teachers—science teachers using a specific teaching approach. Such a specific focus will allow a holistic view of the situation including all its variables. Yin (1984) emphasized that the case study is a suitable design when it is impossible to separate the phenomenon's variables from their context.

As mentioned above, because the main purpose of this study is to construct a holistic understanding of a particular group of teachers' implementation of the SWH within an inservice program as part of their professional growth, an interpretative case study design was adopted for this study to be able to illustrate the complexities of the phenomenon, obtain information from a wide variety of sources, have a "thick" (Guba & Lincoln, 1981, p. 119), or rich, description of the data, and suggest a model for professional growth (Merriam, 1988).
Data Collection Methods

Multiple techniques for data collection were used for the qualitative design. The adoption of such different approaches is needed for sustaining research validity through triangulation. Denzin (1970) emphasized the rationale for this methodological triangulation strategy by explaining that, “the flaws of one method are often the strengths of another, and by combining methods, observers can achieve the best of each, while overcoming their unique deficiencies” (p. 308). When conducting a case study, the raw data collected, which provide depth and detail, are expected to include “detailed descriptions of situations, events, people, interactions, and observed behaviors; direct quotations from people about their experiences, attitudes, beliefs, and thoughts; and excerpts or entire passages from documents, correspondence, records, and case histories” (Patton, 1980, p. 22).

Depth and detailed data require the researcher to get closer “physically and psychologically” (Merriam, 1988, p. 68) to the phenomenon under study (Patton, 1980) and rely heavily on observations, interviews, and documents (Merriam, 1988). Further, questionnaires can be used as a data gathering technique when conducting a case study to support findings from qualitative data and can help in the understanding of field observations (Sieber, 1973). A researcher needs to distinguish between using a survey—that is, a questionnaire to gather more information for a case study—and using a survey as a research genre; the purpose of each is quite different. More details will be provided later (within the questionnaire section) as a rationale to explain the use of quantitative data gathered from surveys to support the description and interpretation of the qualitative data and to emphasize triangulation.
Observation.

The need for rich descriptive data of the teaching practices of all participating teachers in their classrooms is crucial, so as to be able to capture as many variables associated with the teacher's professional growth in applying a student-oriented approach as suggested by the SWH template. Therefore, observations were considered the primary source of data in this study. Observations as well as interviews are considered legitimate, well-known case study instruments, particularly when subjected to checks and controls on validity and reliability (Esterberg, 2002; Merriam, 1988). Using participant observation as a primary source of data in case study research required extensive observations of participants, to be able to capture or record behaviors as they are happening. Merriam (1988) asserted the effectiveness of an observer by explaining that

As an outsider, an observer will notice things that have become routine to the participants themselves, things which may lead to understanding the context. The participant observer gets to see things firsthand and to use his or her own knowledge and expertise in interpreting what is observed . . . (p. 88)

The purpose of the study guided what was to be observed the most. Considering that an observer cannot observe everything, it is helpful to decide in advance the main aspect(s) to focus upon during the observations. In other words, defining observational units is a crucial element in deciding what is it to be observed and focused upon during the observation sessions. As McMillan and Schumacher (1997) stated, “since it is impossible to observe everything that occurs, the researcher must decide on the variables or units of analysis that are most important and then define the behavior so that it can be recorded objectively” (p. 270).
The data collected from observation provided an insight for answering the first and second research questions: To what degree does the inservice professional development program enable each teacher to adopt and implement the SWH as student-centered approach within his/her classrooms? And what is (are) the main characteristic(s) that define different levels of implementation of the SWH? As stated earlier, the SWH teacher template encompasses several dialogical argumentation activities that teachers must promote in their classroom with each impacting the facilitation of such argumentation.

The most important unit of this research analysis was teacher-student and student-student dialogical interaction, as they attempted to construct or derive meaning from the activity. The behaviors observed, therefore, were teacher questions, teacher response to student questions, teacher judgmental phrases, and teacher control of discussion. The teacher behavior in the classroom was affected positively or negatively the level of classroom dialogue either between teacher and students or among students themselves. Thus, the main question that guided the observation of each teacher within the classroom was does the teacher promote dialogical argumentation in classrooms? If yes, who is controlling it?

**Remote-site observations**

Two types of observations were conducted: remote-site and on-site observations. Remote observations were conducted by using video conferencing technology. This technology was used to facilitate the communication with teachers who participated in the study and whose school districts were located more than 20-25 miles from the Iowa State University campus. For some school districts and depending on availability, a district science coordinator conducted an on-site observation along with another independent observer from a remote-site. A minimum of three observations of an entire class period was conducted for
each teacher. In the case of a teacher with multiple classrooms, observations of the same classroom were conducted. The reason for the same classroom observations was to reduce any extraneous variables that emerged from the teacher’s interaction with different groups of students, classroom setting, the time of day, and also the familiarity of the observer as a component of the classroom setting. Further, the three observations were not consecutive so as to allow for teacher professional growth based on the debriefing session and feedback that followed each observation.

Observers had no control on deciding the time for the observations, especially when using the remote-site technology. Each teacher decided the observation time according to his or her schedule and contacted the observer to arrange for an observation session. Such a strategy followed recommendations from Merriam (1988), who explained that an observer cannot decide precisely in advance the observation schedule. The observers were always in contact with the teacher and/or the school district science coordinator to inquire about the implementation of an SWH activity and to increase the level of trust and comfort with the teacher. This not only facilitated the observation, but also assured randomization of the observation time with respect to classroom activity.

Finally, when using remote-site observation, the role of the observer was changed. The remote-site observation inhibited or limited any kind of observer interaction or participation within the classroom activity. Therefore, the observer was merely a spectator of the classroom activity. While the teacher and observer had worked on building a cooperative relationship through the support gained during the unit preparation, the field of observation included a third and important part—the students. Although the teacher explained the reason for the observation to his or her students, the level of curiosity among students cannot be
ignored, especially when observing upper elementary grade level students. To reduce the
distraction caused by viewing remote-site-observer, teachers sometimes turned off the TV set
on the school site before the beginning of the period. Thus, while overt observation was
conducted with respect to the teacher, covert observation was conducted when it came to
students. In accordance with all ethical concerns, all the necessary consent forms regarding
participating in the study including data release and videotaping were completed prior to any
observation.

**On-site observations**

The second type of observation, the on-site observation, was conducted in the
classroom setting. There was no limit to the maximum number of observations in this type of
observation. Some observers decided on a specific day of week to spend in the school, yet
choosing the classroom to be observed depended partially on the teachers' schedule, the
classroom activity on that specific day, and the needs of the teacher; for example, the
observer might decide to observe a specific teacher every week and observe others twice a
month.

This type of observation encouraged the building of a trust relationship not only
between the teacher and the observer, but also between the observer and students. Further,
the observer had the opportunity either to take a role in the classroom activity or merely to be
a spectator. To have a role in classroom activity means to participate in the teaching activity;
however, this could happen only after gaining the teacher's trust and oral permission to
participate during any time of the instruction activity. In other words, such participation may
not occur with all the teachers observed through on-site observation and solely depended on
the teacher's permission. Such interaction, if it occurs, is crucial in a sense that the observer
is modeling in an ongoing action rather than in a hypothetical manner, the desired behavior and/or response to the teacher.

**Issues regarding validity and reliability of observation**

As stated earlier, accounting for internal validity is regarded as accounting for reliability (Guba & Lincoln, 1981). The observational data was collected by five independent observers including the researcher. Two of the observers were district science consultants; the other two were a retired science (biology) teacher and a PhD graduate student in the curriculum and instruction department. Due to the existence of multiple observers, there was a need to account for internal-validity of observations. Thus, three major actions were taken. First, prior to conducting any observations, all observers attended a two-day workshop regarding implementing of the SWH. The focus of the workshop was twofold: training the observers to observe an SWH implementation and conducting a debriefing session afterward to help the participating teachers overcome weaknesses and defining strengths of the implementation. Second, all teachers participating in the study were asked to videotape one of their SWH sessions. Third, observational notes were collected along with specific points highlighted during debriefing sessions.

As the major researcher, the task was to observe the SWH sessions independently, which was done simultaneously through a remote-site or by observing a videotape of the session. Observation notes were taken based on the focus of the observation as highlighted above—that is, the dialogical argument. The observational notes were compared to the notes conducted by the other observers to look for similarities in diagnosing strengths and weaknesses in the implementation. In case the actual observer of the session missed diagnosing more than one issue within the session observed, a phone discussion was
conducted aiming for advice and direction. Further, a copy of the researcher’s feedback to the teacher derived from independent observation notes was given also to the observer to help create a shared observation focus and conduct better future observations. Obviously, continuous interactions with the observers during the time of data collection played a major role in the internal-validity of observation.

The common reliability estimate used for observational research is agreement, which refers to the extent to which two or more persons agree about what they have seen, heard, and/or ranked. That is, when two or more raters independently observe and rank something, will they agree with each others regarding the rating and observations? If yes, then inter-rater reliability is achieved (McMillan & Schumacher, 1997). In this study, two independent raters observed and ranked each teacher SWH implementation. In addition to the major investigator, the retired science teacher, also served as a rater.

To account for consistency of ranking for each teacher’s SWH implementation between the two independent raters, the teachers’ videotapes were used. The two raters independently observed the videotapes and ranked the effectiveness of teacher implementation of the SWH. The rank was based on a scale of 1 to 10, where 1 indicated the lowest implementation rank and 10 indicated the highest. Whenever a different ranking was detected for a teacher, discussions and revisions of the observation notes were conducted until agreement was reached. In case of a failure to reach an agreement based on observational notes, a joint observation of the specific teacher SWH videotape session was conducted to help reach an agreement. The percentage of agreement or the inter-rater reliability between the two raters was 81.25%. Table 1 summarizes the various observational
techniques the researcher used, besides defining the number of teachers observed per each school district and the on-site observer.

Table 1. Researcher observational methods and the on-site observer

<table>
<thead>
<tr>
<th>Observation type</th>
<th>School district</th>
<th>Teacher</th>
<th>On-site observer</th>
</tr>
</thead>
<tbody>
<tr>
<td>On-site</td>
<td>Ames public school</td>
<td>2</td>
<td>—</td>
</tr>
<tr>
<td>Remote-site</td>
<td>Riverside public school</td>
<td>3</td>
<td>Science consultant 1</td>
</tr>
<tr>
<td>—</td>
<td>Riverside public school</td>
<td>1</td>
<td>Science consultant 1</td>
</tr>
<tr>
<td>Videotape</td>
<td>Elk Horn–Kimballton public school</td>
<td>2</td>
<td>Science consultant 1</td>
</tr>
<tr>
<td>Videotape and on-site</td>
<td>Anita public school</td>
<td>1</td>
<td>Science consultant 1</td>
</tr>
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<td>Graduate student</td>
</tr>
<tr>
<td>Videotape</td>
<td>Des Moines public school</td>
<td>1</td>
<td>Science consultant 2</td>
</tr>
<tr>
<td>Videotape</td>
<td>Central junior/high public school</td>
<td>1</td>
<td>Retired teacher</td>
</tr>
</tbody>
</table>

*Questionnaire.*

The term "questionnaire" is used to emphasize its purpose only as an instrument to collect data, because the term "survey" can be misleading for it might imply a research genre or a data-collecting tool. Data collected from a questionnaire is similar to information conducted from a structured interview in which all respondents respond to the same questions in the same order; however, they differ in avoiding the bias that might inevitably occur during a direct contact with the respondents (Schensul, Schensul, & LeCompte, 1999).

Based upon the responses obtained, two forms of questionnaire items are identified: close-form and open-ended. The former, also known as structured or close-ended, indicates that respondents can choose a response only from a predetermined set of responses, while the latter indicates respondents write in responses and elaborate on any item as they want. The choice of which form to use depends on the objective of the items and the advantages and disadvantages of each type. If the purpose is to seek specific individual responses, the open-
ended format is considered the best to use. On the other hand, if the purpose is to obtain general group responses, the closed-ended format might be the best to use (McMillan & Schumacher, 1997).

For this study, a combination of formats was employed. A set of appropriate items was developed to which the participating teachers respond first by choosing either yes or no, followed by providing an open-ended response to explain and reason their choice. The questions were focused on the implementation of the SWH approach in an attempt to understand the teachers’ feelings, beliefs, and experiences regarding the implementation of a constructivist teaching approach in their classrooms. Further, a close-ended item, in which a teacher had to choose among three choices with the choice that matched his or her views of science, was added to the questionnaire to track the relationship between teacher views of science and the level of implementation quality.

The original survey created during the pilot study consisted of seven items mainly focused on the SWH and difficulties associated with implementation. The new questionnaire used in this study included five items additional. The new items were generated to promote a more holistic view regarding the implementation; specifically, the new items inquired about the unit preparation. A copy of the two questionnaires is presented in Appendix A.

**Interviews.**

Interviewing is a common tool of collecting data in qualitative case study research (Esterberg, 2002; Merriam, 1988). An interview is “a meeting of two persons to exchange information and ideas through questions and responses, resulting in communication and joint construction of meaning about a particular topic” (Janesick, 1998, p. 30). Therefore, interviewing someone is like having a conversation between two people, the interviewer and
the interviewee, yet a purposeful conversation in which the interviewer asks questions to find out through the interviewee's responses what is in and on his or her mind with respect to a specific topic. Patton (1980) emphasized the importance of interviewing as data collecting technique stating that

We interview people to find out from them those things we cannot directly observe . . . We cannot observe behaviors that took place at some previous point in time. We cannot observe situations that preclude the presence of an observer. We cannot observe how people have organized the world and the meaning they attach to what goes on in the world—we have to ask people questions about those things. The purpose of interviewing, then, is to allow us to enter into the other person's perspective. (p. 196)

Based on the amount of control exerted by the researcher during the interview, different types of interviews are defined. These are structured, semistructured, and unstructured interviews. Questions to be asked in structured interviews must be prepared in advance and asked exactly as written, which means that the interviewer is not allowed to rephrase the question using the interviewee's words if the latter does not understand. Moreover, the interviewer is committed to read any direction as written and follow the exact order of the questions. Further, the interviewer should remain neutral during the interview time and not reveal any personal information to maintain unbiased data; otherwise the "interviewees will tend to give the responses that they think the interviewer wants to hear" (Esterberg, 2002, p. 86). This type of interview grants too much control to the interviewer, such as controlling the questions and how they are worded, and risks losing information due to misunderstanding of the question on the part of the interviewee and the lack of opportunity
for clarification on the part of the interviewer. Thus, researchers rely on this type of interview
“when a large sample is to be surveyed, when hypotheses are tested, or when quantification of results is important” (Merriam, 1988, p. 73).

On the other hand, unstructured interviews are useful when the interviewer does not
know enough about a phenomenon to ask relevant questions, so no predetermined set of
questions exists and “the interview is essentially exploratory” (Merriam, 1988, p. 74). Such
interviews are conducted in a field setting and tend to be more spontaneous in topics arising
from the situation or behavior at hand (Esterberg, 2002). Therefore, the interviews are
considered as conducting real conversations between the researcher and the respondent in
which both are responsible for continuing the conversation.

Semistructured interviews are guided by a list of questions or issues to be focused
upon and explored, but interviewers are not committed to the exact wording or the order of
the questions. In other words, semistructured interviews fall in the middle of the spectrum
between the highly structured and the unstructured interviews with respect to the degree of
control granted to the researcher.

To gather more in-depth information and allow interviewees to express their opinions
and ideas in their own words, the interviewer needs to listen very carefully to the
interviewee’s responses and be able to follow his or her lead. Several researchers indicated
that semistructured interviews are desired when conducting interpretative case studies to
obtain more in-depth information about the situation or phenomenon under study (Merriam,
qualitative researchers choose semistructured or unstructured interviews for the greater depth
of insight they give into the lives of their research participants” (p. 87).
As a person's knowledge of a topic can range from fact to opinion, Patton (1980) suggested six categories that an interviewer might explore to stimulate different interviewee responses; these are behaviors, values, feelings, knowledge, sensory, and demographic. Four types of questions—hypothetical, devil's advocate, ideal positions, and interpretative—can guide the process of deciding on interview questions (Strauss, Schatzman, Bucher, & Sabshin, 1981). Hypothetical questions seek respondent behavior or opinion in a particular situation. Devil's advocate questions challenge a respondent to consider an opposing view. Ideal position questions ask for description of an ideal situation. Finally, interpretative questions target tentative interpretation of the respondent. Yet conducting a successful interview requires researchers to form interview questions in familiar language (Merriam, 1988; Schensul et al., 1999). Obviously, there will be no conversation without a common understandable language. As Patton (1980) asserted,

> Using words that make sense to the interviewee, words that reflect the respondent’s world view, will improve the quality of data obtained during the interview. In many cases, without sensitivity to the impact of particular words on the person being interviewed, the answer may make no sense at all—or there may be no answer. (p. 227)

On the other hand, researchers also suggest avoiding specific forms of questions (Esterberg, 2002; Merriam, 1988; Patton, 1980; Schensul et al., 1999). For example, avoid asking multiple questions or a series of single questions. Such questions deprive the respondent of the opportunity to fully express his/her response. Leading questions also should be avoided because they set up the interviewees to accept the interviewer's point of view or agree upon a different world view than what they really believe. Further,
interviewers should avoid asking dichotomous questions, such as yes/no or agree/disagree questions. Interviewing is aimed at obtaining more meaningful responses through open-ended questions while close-ended questions limit the answer to two possible responses, which might be considered too simple to be valued. Finally, although the researcher does not completely agree it is worth mentioning that Patton (1980) warned interviewers about using ‘why’ questions. People do not know why they do things and this not only leads to difficulties in making causal inferences, but also may lead into asking a series of why questions. Esterberg (2002) further explained that an interviewee may feel intimidated and tend to provide defensive response to account for his or her action.

Merriam (1988) highlighted issues regarding the relationship established between the interviewer and the interviewee. In structured interviews, the interviewers remain as neutral as possible to avoid biased information. On the other hand, in semistructured or unstructured interviews, the interviewers need to develop a trust relationship also known as developing “rapport” with his/her interviewees. Esterberg (2002) emphasized the importance of developing such trust when stating the following:

If the person you are interviewing doesn’t trust you or feel comfortable in your presence, then the interview is unlikely to go well. After all, why should someone take the time or effort to interview with you? What’s in it for them? Even if participants do agree to an interview, they may not be willing to talk honestly or discuss intimate details about their personal lives if they do not feel some level of trust. (p. 91)

Although interviewers need to develop enough rapport to get interviewees to talk to them, they still need to remain neutral and nonjudgmental. Rapport with respect to the interviewer
and neutrality with respect to the information is needed, regardless of how much the
responses provided violate the interviewer's standards. Patton (1980) asserted the difference,
stating that,

At the same time that I am neutral with regard to the content of what is being said to
me, I care very much that that person is willing to share with me what they are saying.

Rapport is a stance vis-à-vis the person being interviewed. Neutrality is a stance vis-
à-vis the content of what that person says. (p. 79)

Teachers' semistructured interviews

In this study, a semistructured interview was conducted with each teacher after unit
implementation to obtain in-depth information about the SWH as a student-oriented approach.
All teachers involved were informed of the study requirements: observations, videotape,
questionnaire, and interviews in advance as part of their agreement to enroll in the
professional development. An electronic mail notice was sent to all teachers to determine a
time for the interview based on their available schedule.

Similar to observations, a remote semistructured interview, using a telephone cassette
recorder, was individually conducted with each teacher located 30 miles away from ISU
campus. Other teachers located less than 30 miles off campus were also interviewed
individually either in their school or on the ISU campus based on their choice. Each
interview lasted between 40 and 50 minutes depending on the nature of the conversation.
Before interviewing, each teacher was reminded of his/her right to choose not to respond to a
particular question or to withdraw from the interview. Also, each teacher was assured that the
interview focused on his/her thoughts; therefore, there were no right or wrong answers and
his/her opinion, SWH experience, and reflection were what the researcher was looking for.
Schensul and colleagues suggested that "researchers should warm up respondents by beginning with interesting but nonthreatening questions, and follow up with more challenging material" (Schensul et al., 1999, p. 155). They further provided a few points to consider when ordering an interview questions log. For instance, questions should be ordered temporally, from earlier events to more recent events. In general for all teachers, the interview began by asking a few questions of each teacher's background, that is, extracurricular activity, years of experience, followed by asking questions to elaborate on their responses to the teacher questionnaire, such as their opinion regarding the unit preparation and how it differs from traditional preparation of a unit. Finally, the interview ended by asking about their opinion, experience or specific behaviors, and/or hypothetical contexts about classroom interaction to seek their response. Following the teacher's lead, follow-up questions were based on the responses from the teacher. Nevertheless, the interviews revolved around the implementation of the SWH as a tool for providing a context for dialogical discussion and argument, and the teachers' understanding of the impact of the SWH on promoting student learning. All interviews were transcribed.

**Criteria for Levels of Implementation**

Based on a previous study that used the SWH for teaching general chemistry laboratory course for college level students (Omar, Hand, Greenbowe, 2002), three criteria to define teacher level of implementation were constructed (figure 4). Building on the question that guided teacher observations—does the teacher promote dialogical argumentation in classrooms? The main criterion in defining the quality of teacher level of the SWH implementation is the dialogical interaction in the classroom. An observer can define the quality level of the SWH implementation based on teacher-student interaction and teacher
promotion of student-student interaction. The kinds of responses the teacher used to respond to student questions and/or responses to the teacher’s questions impacted the classroom interactions. The questions the teachers ask in classrooms can promote or limit classroom discussion, for example, when teachers ask more factual questions that target specific response, less interaction will occur in classroom as such low-level questions require students only to have knowledge and comprehension of the content. On the contrary, more open-ended questions that seek justification of student thinking will promote more dialogical interaction and encourage students to analyze and evaluate the concepts, which in turn will help them make sense of them.

- Dialogical interaction
  - Types of teacher questions
  - Teacher response to student’s question
  - Teacher response to student’s answer
- Controlling of knowledge
  - Sharing the ground or power relationship (non-threatening environment)
  - Types of inquiry investigation
  - Promoting public aspect of knowledge
- Unit preparation
  - Big ideas of the unit (teacher content knowledge)
  - Building on students’ prior knowledge
  - Choice of SWH activities to promote big ideas
  - Unit assessment (conceptual questions)

Figure 4. Criteria for ranking teacher level of implementation

Further, teacher attention to the strategies required by the SWH teacher template helps define his or her level of implementation. Promoting different phases of negotiation during an SWH activity, such as negotiation of beginning questions, negotiation of testing procedures, and negotiation of data collecting, reflected the teacher’s understanding of the
impact of each phase on promoting student learning and, in turn, indicated his or her understanding of the constructivist teaching approach.

The second criterion used to define the quality of the teacher's SWH implementation is the control of knowledge. If the teacher dominates the classroom discussion rather than adopting the role of "a debate mediator," students' sharing of ideas and the reflection on other students' ideas will be controlled by the teacher. Such learning environments not only limit and threaten student participation, which in turn has an impact on his/her learning, but also defines the type of relationship between the teacher and students: sharing "the floor" relationship or a power relationship. In other words, the more controlling the teacher is, the more didactic the teacher is.

Another component in the second criterion was the type of SWH activity. The inquiry models (Windschitl, 2003) reflect teacher belief and interpretation of the constructivist learning theory and in turn, affect classroom practice. Using structured inquiry indicates the didactic approach the teacher use, which reflects the controlling of learning. The highest level of inquiry model, that is, open inquiry, on the other hand, reflects the authenticated learning environment in which students decide the activity question, the investigation procedure, and materials needed.

Promoting the public aspects of knowledge was also a component that influenced the observer's decision for scoring the criteria of knowledge control. Teachers, who invited their students to discuss their claims and evidence whether in small or large group discussions, were promoting the public aspects of knowledge. The large group discussions of the meaning generated from the activity were focused on the students. The use of the board to share different claims and the validity of a claim based on the evidence were very much the
students' responsibility. The teacher adopted the role of discussion mediator rather than information dispenser.

The third criterion to define levels of implementation is related to the unit preparation. As stated in the previous chapter, the SWH supports constructivist learning/teaching approach, in turn; the unit preparation using the SWH should differ from the traditional teaching approach. Teachers no longer follow the textbook sequence and covering information, instead they center the units on a few big ideas (not to exceed five). Indeed, deciding the big ideas reflects each individual teacher understanding of the content knowledge. In doing this, teachers need to inquire about their students' prior knowledge to promote constructing the new ideas on previous conceptual structure.

Further, the SWH inquiry activities with respect to promoting student learning of the big ideas are another component in the unit preparation criterion. Teacher choice of appropriate activities to promote learning of big ideas is crucial to promoting students understanding of the role of inquiry investigation to the knowledge claimed, as a result of completing the investigation.

The designing of conceptual questions to assess understanding is the final component in this criterion. Teachers tend to ask direct recall short answer questions or extended recall questions. Shifting toward constructivist teaching requires teacher to design questions that enable students to apply the school knowledge to everyday life context. Such questions are more intellectually challenging for students and assess their understanding of the knowledge rather than their capability to memorize the knowledge.
Ranking Mechanism

Each teacher was ranked based on his/her level of implementation. The ranking mechanism consisted of three composite ranking scales. McMillan and Schumacher (1997) defined a scale as a series of degrees, levels, or values that describe various degrees of something. Because people tend to assess their belief and opinion in terms of gradations, scales are widely used. Assigning numbers to things enables the differentiation among them.

The first ranking scale is a 10-point scale, specifically targeted the first criterion—promoting dialogical interaction—with one indicating low interaction and 10 indicating high interaction. The promotion of dialogical interaction and student argument are considered the major demand of the SWH and reflect a shift in instructional practice. The 10-point scale provides more opportunity for the researcher and the independent rater to generate a ranking for each teacher’s implementation. These 10 points were further classified in three levels of ascending quality of implementation: where 1-4 indicated a low level of implementation reflecting minor shift from the traditional teaching approach; 5-7 indicated the a small shift towards student-oriented classroom; and 8-10 indicated a greater shift towards student-oriented classroom.

The second and third scales specifically targeted the second and third criterions respectively—controlling the knowledge and unit preparation. Each scale was a 5-point scale with 1 point reflecting the first level, 3 points reflecting the second level, and 5 points reflecting the third level, while 2 and 4 points indicated transition levels. The 5-point of controlling the knowledge scale reflects the degree of teacher controlling knowledge in his or her classroom in which the low level implies knowledge transfer. Further, the 5-point unit preparation scale reflects teacher success in preparing for the unit(s) from constructivist
teaching perspectives (Simon, 1995). As stated above, to shift teaching practices to constructivist teaching approaches, requires that teachers have a robust understanding of their content knowledge.

**Participating Teachers**

Eighteen science teachers participated in the SWH project, which was being conducted in association with the Iowa Department of Education to improve science teaching in Iowa. Therefore, science consultants from different Area Educational Agencies (AEAs) collaborated with the research group at ISU to assist in the science teacher professional development program, including helping teachers planning for the unit such as limiting the unit to few big ideas, finding activities, creating unit conceptual understanding, and organizing and conducting on-site observations. They further helped in encouraging the teachers to communicate with the project staff and the data collection procedures.

All participating teachers implemented their SWH unit(s) during the 2003-2004 academic school year, from September 2003 until the end of March 2004. The teachers involved teach several science disciplines: general science, chemistry, physics, biology, and/or earth science to a wide range of grade levels: upper elementary, middle school, and secondary school. Each teacher holds a different educational degree with different experience in traditional teaching.

Descriptions of each teacher's background, implementation time, and the unit(s) chosen for the SWH implementation, including the big ideas, the SWH activities, and the conceptual questions constructed to evaluate student understanding of the unit concepts are presented in chapter four. A pseudonym was assigned to each teacher, to maintain confidentiality. The 18 teachers reported in this study were from seven school districts. All
districts involved, including participating teachers, unit(s) implemented, and case study design are described in Table 2.

**Professional Growth Program**

According to Bowyer, Ponzio, and Lundholm (1987), eight to sixteen hours of inservice program time is required to successfully cause change in teacher’s current pedagogical practice. That is, a minimum of two to four days of inservice workshop is required. All participants were involved in an initial workshop that laid down the basis of constructivism as a learning theory, tackled their epistemological beliefs toward teaching and learning, and modeled a scientific activity using the SWH approach as a first phase of their professional growth. Several workshops were conducted at the Iowa State University campus or at the school site. Some of the teachers were able to attend the 3 day professional development workshop at Iowa State University campus. While some teachers attended three one-day workshops, other teachers attended in school two-day workshops. However, during this experience, attention was devoted to the desired teacher role and the concept of student oriented teaching approach. The teachers reflected on the required teacher role and were provided with suggestions to improve the implementation of the activity. Further, the teachers tackled issues related to a unit preparation in which they drew a concept map of what they perceive as the most important issues that guide their preparation of a unit. This activity aimed to put more emphasis on the big ideas for each unit and science standards rather than on student goals. The workshop also informed the teacher of the research requirements—that is, the research protocol and the student document action needed.
Table 2. Teacher timetable of SWH unit implementation

<table>
<thead>
<tr>
<th>District</th>
<th>Teacher</th>
<th>Grade</th>
<th>Area</th>
<th>Unit</th>
<th>Design</th>
</tr>
</thead>
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<td>Ecology</td>
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<td></td>
<td>Cell</td>
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<td>Genetics</td>
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<td></td>
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<td>Ecology</td>
<td>No control</td>
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<tr>
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<td></td>
<td></td>
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<td>Cell energy</td>
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<td></td>
<td></td>
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<td>Control/treatment</td>
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<td>Brad</td>
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<td>Physical science</td>
<td></td>
<td>Control/treatment</td>
</tr>
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</table>

Taking into account that each teacher needed sufficient time for training and evaluating the new teaching approach, several one-on-one sessions targeted to support each teacher in implementing a unit were also planned. Such one-on-one sessions were derived from each teacher's needs and conducted following different means according to the location.
of each teacher's school. In addition to direct communication with nearby teachers, electronic 
mail and telephone were used to ease communications with teachers in more remote 
locations.

Each participating teacher in the professional program was asked to choose a unit or a 
topic from his/her discipline to teach following the SWH format. Giving freedom to teachers 
to choose the topic had a twofold purpose. First, the teacher's choice reflected his/her 
confidence with respect to content knowledge and ability to guide and scaffold students' 
learning and discussion. Second, to account for teacher readiness for change, no imposition 
was made to any specific unit to implement; instead, each teacher chose a unit as his or her 
starting point. The researcher was guided by Gremill (1983, p. 270), who argued that 
readiness is not reflected merely by the teacher's willingness to change; rather, it reflects a 
"state of open-mindedness" which would facilitate teacher's deliberate evaluation of the new 
approach. This is the focus of this research on the SWH.

In planning for the unit, each teacher decided on the big ideas of the unit or topic, and 
was instructed to not exceed five general ideas. Within each general idea, there were a few 
science concepts to be discussed and covered. A one-on-one discussion about these ideas 
with each teacher was offered as a part of the inservice professional development. Although 
such discussions helped teachers identify the general ideas and generate the specific concepts 
and their relationship to other ideas, the final decision of the big ideas was left to the teacher. 
Teachers had the freedom to accept or reject the suggestions posed during this one-on-one 
discussion.

The second step in preparing for the unit or topic was to choose at least three 
activities to implement following the SWH format. Limiting the minimum number of
activities to be completed was based on a study by Hand, Wallace, and Prain (2003), who indicated that a minimum of three SWH activities was needed to cause a detectable change in a teacher's instructional approach and in turn have impact on students' understandings of the scientific conceptual knowledge. The activities chosen by the teachers were required to enable students' inquiry, promote classroom negotiation of science knowledge, and allow for higher-level student thinking. Each teacher had a one-on-one support session to help with the activity selection. Some participants sought advice regarding their choice of the activity, in particular these teachers wanted advice on how suitable the activities would be in promoting the targeted big idea. Others asked for help finding activities due to limited resources available at their school. In such cases, different activities were provided; however, the teachers still had the freedom to use or discard them. Further, teachers may have agreed on the core idea of a provided activity, but reconstructed it to fit their classrooms and teaching pedagogy.

As a final step in the unit or topic preparation, all participating teachers were asked to construct a student evaluation test on the selected unit or topic. Since the SWH is an inquiry-based tool that focuses on conceptual understanding rather than content retrieval, the student evaluation test could not be based solely on multiple-choice questions. Teachers had to include questions targeted at evaluating students' understanding of scientific concepts and the relationships between concepts rather than asking mere recall questions. The tests created were composed of two parts: traditional recall (multiple choice) questions and conceptual questions. A minimum of two conceptual questions and 15 multiple-choice questions were required. Each teacher was provided, upon request, with examples of conceptual questions, such as extended conceptual questions, analogy, and/or applying knowledge to a different
context. As a part of the inservice professional program, each teacher individually received a feedback on the conceptual questions created. Still teachers have the absolute freedom to encompass or deny the provided suggestions.

The second phase of the teachers' professional growth was based on the observations of the implementation of each activity following the SWH format. After each teacher observation, s/he was involved in a one-on-one debriefing session with the on-site observer that highlighted some aspects of the implementation. The purpose of the one-on-one debriefing session was fourfold: first, to increase the level of confidence and trust between the teacher and observer; second, to promote the teacher's awareness of certain behaviors observed; third, to highlight the pedagogical areas that needed improvement and, finally, to suggest some strategies that the teachers might use to improve their implementation of the required student-oriented approaches in the future. The debriefing sessions between the teacher and the observer were conducted through telephone or video conferencing whenever remote-site observations were conducted. Further, written feedback that included a summary of the debriefing session and highlighted suggestions for future implementation was sent electronically to the teacher to overcome any miscommunications that might occur during the oral debriefing session.

Quantitative Research Design

As mentioned earlier, embracing different procedural approaches not only adds to research validity, but also assure generalizability of the outcomes. The quantitative approach in this study is used to answer the third research question—what is the effect of teachers' levels of implementations of the SWH on students' learning of science concepts? Such an approach will enable the research to investigate the effect of teacher levels of
implementations of the SWH on students' performance with respect to student gender and achievement level. Further, the researcher was aiming for a replication of the results obtained during the 2002/2003 school academic year pilot study from the analyses of almost 750 students of 10 teachers (Gunel, Akkus, Hohenshell & Hand, 2004).

The type of outcome expected from such a question basically indicates a cause-and-effect relationship between two variables, where the independent variable (teacher level of implementation) causes or determines the presence of the dependent variable (student performance on conceptual questions). Such causal relationship is appropriate for experimental design (Johnson & Christensen, 2000; Merriam, 1988). In educational research, it is difficult to have a true experimental design due to lack of randomization, limited control of variables, and/or sometimes the lack of a control group; therefore, quasi-experimental designs might be used instead (McMillan & Schumacher, 1997; Merriam, 1988). Johnson and Christensen (2000) defined quasi-experimental research designs as experimental research designs that do not provide full control of potentially confounding variables. They explain further that “the primary reason that full control is not achieved is because participants cannot be randomly assigned to groups” (Johnson & Christensen, 2000, p. 255).

Among the different quasi-experimental designs, a nonequivalent control group design (Campbell & Stanley, 1966) and untreated control group design with pretest and posttest (Cook & Campbell, 1979) are the most common designs used in educational research. In both designs, both groups (treatment and control) are given a pretest and a posttest; however, the assignment of students into each group, of course, is not random. Rather, the assignment of the treatment to one group or the other is assumed to be random (Johnson & Christensen, 2000). The use of the phrase nonequivalent or unmatched group refers to: 1) the
lack of randomization of students to each group, which is considered a crucial element to the validity of causal conclusion, and; 2) the lack of convincing evidence that the groups are essentially the same (Campbell & Stanley, 1966). On the other hand, untreated control group design with pretest and posttest refers merely to the lack of randomization of assigning students to group.

Studies that are trying to establish a cause and effect relationship must account for potential problems that arise from confounding, which occurs when part or all of a significant association between two variables arises through both being causally associated with a third variable (Keppel, 1991). Such confounding is a threat to research validity. Campbell and Stanley (1966) illustrated several confounded extraneous variables can jeopardize internal validity: history, maturation, testing, instrumentation, and selection. These variables offer plausible hypotheses that provide explanations of the difference between pretest and posttest competitor to the hypothesis that merely the treatment causes the difference.

History is related to events that might occur in the time between the administration of the pretest and posttest. Maturation refers to biological and psychological processes that vary with the passage of time. Testing is related to the impact of the test itself, defined as reactivity. The instrumentation is related to issues used to measure the effect, such as grading or observation. Selection is related to randomization. Further, the interaction effects that might occur between any of these variables—for example, selection and maturation also contribute to the confounding (Campbell & Stanley, 1966; Johnson & Christensen, 2000). A control group, although might be nonequivalent or untreated, accounts for some of these confounded extraneous variables. Campbell and Stanley (1966) asserted that “the more similar the experimental and the control groups are in their recruitment, and the more this
similarity is confirmed by the scores on the pretest, the more effective this control becomes” (p. 47-48).

Thus, untreated control group design, with pretest and posttest, is considered more powerful than the one-group pretest-posttest design, in which a posttest is administered to participants in a single group after they have been pretested and exposed to an experimental treatment (Johnson & Christensen, 2000). Campbell and Stanley (1966) further argued the strength of the untreated control group design with pretest and posttest, stating the following:

for purposes of internal validity, we can regard the design as controlling the main effects of history, maturation, testing, and instrumentation, in that the difference for the experimental group between pretest and posttest (if greater than that for the control group) cannot be explained by the main effects of these variables such as would be found affecting both the experimental and the control group. (Campbell & Stanley, 1966, p. 48)

Nevertheless, the one-group pretest-posttest design is still widely used in educational research when nothing better can be done. Cook and Campbell (1979) categorized the one-group pretest-posttest design among the quasi-experimental designs that do not permit reasonable causal inferences, while Campbell and Stanley (1966) categorized it as one of the pre-experimental designs. However, Johnson and Christensen (2000) categorized it as one of three weak experimental designs. Yet, they all agree upon the weakness of the inferences drawn from such design compared to the inferences drawn from a nonequivalent and untreated control group design with pretest and posttest.

Considering that the focus of this study is to investigate the effect of levels (quality) of implementation on student performance, and because such effect might differ according to
student gender and achievement level, the demand arose to have a more complicated design with more than one independent variable. Therefore, three independent variables were defined: gender, achievement level, and levels of implementation. Gender, of course, has two levels of variation—males and females, while student achievement level has three levels of variation—low, middle, and high, and teacher implementation has three levels of implementation corresponding to three different qualities of SWH instruction. Thus, each of the 18 combination cells of the three independent variables in 2 x 3 x 3 factorial design demands random assignment of participants. Hence, educational researches do not have the power of conducting a true experimental design due to the non-feasibility of randomization, such a factorial design is not possible to adopt for the SWH study; rather it is possible to adopt for the analysis of student outcomes.

Nevertheless, adopting such factorial design for analyzing student outcomes demands not only implementation of the same teaching intervention (the SWH), but also demands that the researcher pays more attention to controlling other extraneous variables, such as the science unit, big ideas, duration of unit implementation, SWH activities, grade level, and assessment test, including the conceptual questions. Meeting all these demands would enable the researcher to determine cause-and-effect relationship while maintaining internal validity (Campbell & Stanley, 1966).

Consequently, for the 18 teachers in the SWH project, two designs were used. On one hand, the teachers, who joined the SWH in the pilot study during 2002/2003 school year, implemented one-group pretest-posttest design. New teachers joining the professional development program, on the other hand, followed the untreated control group design with pretest and posttest. Further, some science teachers, who were teaching in a small school in
which only one class per grade level existed whether they were familiar with the SWH or not, followed a one-group pretest-posttest design.

**Issues Regarding Quantitative Research Validity**

Controlling for nuisance (extraneous) variables is needed to account for the internal validity of quantitative designs—that is, the elimination of biases that might invalidate any conclusions drawn from the study (Keppel, 1991). Although a one-group pretest-posttest research design is used, the main effect of teacher’s level of implementation on student outcomes according to their achieving level and gender was able to be investigated. Hence, deciding teacher’s level of implementation was drawn from the qualitative approach, which achieves validity through the observation instrument used to define the quality of implementation for each teacher.

Further, to overcome the bias associated with the pretest-posttest difference (widely known as) gain scores, this study analyzed student improvement score (IS) instead, which is the normalized student gain score (Harper, Etkina, & Lin, 2003). The IS was calculated as a percentage of potential gain achieved by each student (Hake, 1998) according to the equation

$$\text{IS} = 100 \times \frac{(\text{posttest score} - \text{pretest score}) - \text{r} (\text{pretest total score} - \text{pretest score})}{\text{pretest total score} - \text{pretest score}}.$$ 

Finally, to account for matching groups due to the lack of randomization of assigning students to group, a standardized test (called baseline test) were administered to all students prior to any implementation of the SWH. The baseline test, which consists of three versions, were constructed using items drawn from the Third International Mathematics and Science Study (TIMSS) and National Assessment of Educational Progress (NAEP) standard tests, in which the same ratio of each science area was followed for each test. Each version of the baseline test targeted different student populations upper elementary level (fourth to sixth
grade) is population one, middle school level (seventh to ninth grade) is population two, and high school level (tenth to twelfth grade) is population three.

Results of students’ baseline test data were collected for statistical analysis of students’ general scientific knowledge prior to conducting any treatment, to account for any sources of variability among students’. The internal consistency coefficient (Cronbach Alpha) reported for each population baseline test was obtained from 739 students of 10 teachers involved during the pilot study, conducted during last academic year 2002/2003. The internal consistency coefficients obtained from 1362 students of 18 teachers participated to the study during the 2003/2004 academic year reflect high internal consistency. Table 3 contained information of each population baseline test items.

Table 3. Reliability coefficient and percentage of items for each baseline test

<table>
<thead>
<tr>
<th>Baseline</th>
<th>Population 1</th>
<th>Population 2</th>
<th>Population 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal Consistency Coefficients 2002/2003</td>
<td>.70</td>
<td>.71</td>
<td>.67</td>
</tr>
<tr>
<td>Number of Students</td>
<td>56</td>
<td>389</td>
<td>294</td>
</tr>
<tr>
<td>Internal Consistency Coefficients 2003/2004</td>
<td>.68</td>
<td>.67</td>
<td>.52</td>
</tr>
<tr>
<td>Number of Students</td>
<td>177</td>
<td>916</td>
<td>269</td>
</tr>
<tr>
<td>Grade Level</td>
<td>4-6</td>
<td>7-9</td>
<td>10-12</td>
</tr>
<tr>
<td>Total Items</td>
<td>18</td>
<td>20</td>
<td>21</td>
</tr>
<tr>
<td>% Life Science Items</td>
<td>45</td>
<td>30</td>
<td>19</td>
</tr>
<tr>
<td>% Physics Items</td>
<td>33</td>
<td>30</td>
<td>42</td>
</tr>
<tr>
<td>% Earth Science Items</td>
<td>11</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>% NOS Items</td>
<td>11</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>% Chemistry Items</td>
<td>—</td>
<td>15</td>
<td>19</td>
</tr>
</tbody>
</table>

Statistical Analysis

All statistical analysis for student scores was calculated using the Statistical Package for the Social Sciences (SPSS) version 11.0. Because two quantitative designs were used, the analyses used differ with respect to the independent variable used. For teachers who used
one-group pretest-posttest design, student outcomes on conceptual questions total and students IS on conceptual questions total were analyzed as the dependent variables with teacher’s level of implementation as the independent variable. For the teachers who implemented untreated control group design with pretest and posttest, group (control and treatment) was used as the independent variable when analyzing student outcomes on conceptual questions total and students IS on conceptual questions total as the dependent variables.

The above variables clearly indicate that the researcher intention to use the individual student score as the unit of analysis instead of the class mean. In doing this, the researcher is building upon a conclusion drawn by Herron and Luce (1978) that unless the researcher provides evidence that account for matching groups due to the lack of the randomization of assigning students to groups (only randomization of assigning classes to groups existed), the class mean is considered preferable unit of analysis than individual student score. However, they asserted that when dealing with the choice of ignoring the results of a study merely because the researcher used the incorrect unit of analysis, “the better choice is to accept the results as “probably correct”. This conclusion is based on the assumption that the individuals are randomly assigned to class sections, however.” (Herron & Luce, 1978, p. 302).

To account for similarities in students’ science knowledge prior to the study, analyses of variance (ANOVA) of student scores on the baseline test and the pretest conceptual questions were conducted. These analyses were used to detect any source of variability in student general science knowledge, and in particular unit knowledge among groups prior to the SWH unit implementation. Such analyses were essential to account for similarity of the intact groups prior to the SWH intervention to maintain research internal validity.
In order to investigate the impact of the SWH on student outcomes after the unit implementation, three types of analyses of covariance were used. For case studies following untreated group design, ANCOVA was used to detect the impact of the SWH on posttest conceptual question score among group after controlling for pretest score and ANCOVA was used to detect the impact of the SWH on conceptual question improvement score among group after controlling for baseline test score. A 2 x 2 ANCOVA was used to detect the impact of the SWH on posttest conceptual question score according to group and gender after controlling for pretest score. A 2 x 2 x 3 ANCOVA was used to detect the impact of the SWH on posttest conceptual question score according to group, gender, and student achievement level after controlling for pretest score.

For case studies following one-group pre-posttest design, ANCOVA was used to detect the impact of the SWH on posttest conceptual question score among teacher (or teacher rank) after controlling for pretest score and ANCOVA was used to detect the impact of the SWH on conceptual question improvement score among teacher (or teacher rank) after controlling for baseline test score. A 2 x 2 ANCOVA was used to detect the impact of the SWH on conceptual question improvement score according to teacher (or teacher rank) and gender after controlling for baseline test score. A 2 x 2 x 3 ANCOVA was used to detect the impact of the SWH on posttest conceptual question score according to teacher (or teacher rank), gender, and student achievement level after controlling for baseline score.

The baseline scores were used to define student levels of achievement—that is, students scoring within half standard deviation of the mean are the middle achievers, students scoring less than one standard deviation below the mean are the low achievers, and students scoring more than one standard deviation above the mean are the high achievers. This
classification system was used, taking into account that 34% of student scores fall within half standard deviation of the mean, in the middle achievement level under the normal distribution, while 16% on each end represent the high and low achieving levels.

**Summary**

Many professional development programs were carried out to help inservice science teacher implement an inquiry-based science approach driven from constructivist teaching/learning theory. This study was aiming to define criteria associated with inservice science teacher implementation of student-oriented teaching approach. The science writing heuristic (SWH) was the inquiry-based tool used to guide and support the inservice science teacher participated in the SWH professional development partnership project.

Accomplishing the study goal required the collection of rich descriptions of teacher implementation of the SWH tool. Different data collecting procedures were used, such as observation, questionnaire, and interview. Further, a combined approach qualitative and quantitative procedures were used to provide more support for the data collected from this study.
CHAPTER FOUR

Overview of Participating Teachers and Units

In this chapter, descriptive information of each teacher's background, teaching experience, and extracurricular school activities are presented. Also, information related to the SWH unit implementation, such as the big ideas of the unit, SWH activities, and conceptual questions are presented. The background and unit information are presented according to teacher school district. Teachers from the same school district are clustered together and reported one after the other.

As stated earlier, seven school districts participated in the SWH partnership project conducted with the Iowa State Department of Education with each district having a different number of teachers involved. The seven school districts were represented in three clusters. The first cluster consisted of the largest number of teachers participating from one school district. The second cluster consisted of three school districts located in area educational agency 13. The third cluster consisted of the last three school districts. Teachers from the same district are presented according to the level they taught beginning with higher-grade levels—secondary to upper elementary. Within the same grade level, teachers were reported in descending order according to years of experience in teaching.

Cluster One

Boone Public School District

Boone was the largest district involved in the SWH project with six science teachers involved three of which were teaching in middle school and three in the high school. The population included one female and five males. They all participated in the pilot study conducted during the 2002-2003 academic school year in which they implemented one unit
per semester. All teachers were able to attend the three-day professional development workshop. The focus of the workshop was described in the method chapter. Up to the deadline time of data gathering for this study (March, 2004), some teachers had implemented only one unit, others had implemented up to four units. Information of the first unit implemented is reported below. Other unit descriptions are reported in Appendix B.

John.

John is the most experienced science teacher and has taught high school biology for 28 years. Before joining his current school 18 years ago as a biology teacher, he taught five different science subjects for 10 years in a small school district in Iowa. In addition to his bachelor’s degree in biology, John has a master’s degree in education. John participates in school extracurricular activities, coaching football during the fall and basketball during the winter.

During the pilot study, John implemented the SWH approach with one unit per semester. The two units were genetics and classification. In the beginning, he was uncomfortable with changing his teaching strategies and being observed at the same time. Yet, by the end of his first unit implementation, he was more relaxed and gained more confidence with the SWH approach. He reported noticing a difference in student interaction between the traditional and the SWH approaches.

John taught biology to 90 high school students in five class periods with nearly all of them being in tenth grade. This year, he decided to participate in the project by using the SWH approach for the entire year. The results reported in this study, however, are drawn from the implementation of four consecutive SWH units: ecology, cells, cell energy, and
John and another biology teacher from his school, Gary, decided to team up together to help each other in the unit preparation and implementation. They had planned to meet once or twice before each unit to share the big ideas of the unit, brainstorm ideas for SWH activities, discuss the unit assessment test including the conceptual questions, and talk about difficulties during implementations. Unfortunately, due to time discrepancies between the two teachers resulting from their class schedules and their obligations to extracurricular activities after school, the two teachers were not able to get together and discuss each unit collaboratively as they had planned. Therefore, such teamwork was only carried out for the first unit, ecology, in which both teachers centered the unit on the following big ideas:

- Interdependence of organisms
- Cycles of matter and flow of energy
- Succession
- Human impact

Three SWH activities were implemented in this unit. The first SWH focused on similarities and differences among different biomes. The second activity was derived from the first in which students discuss the common and specific factors that affect different biomes. The last SWH activity, focused on human overcrowding in biomes, which influences energy needs and impacts pollution. Students looked at the impact of removing an energy source on the biome. The unit assessment test included the following conceptual questions:
1. Using your biome as an example, how would you explain the relationships between the living organisms present? What relationship exists between the living and non-living factors in the biome?

2. Predict what would happen to the organisms in your biome if the earth's climate became hotter and rainier. (If your biome was a tropical rain forest, predict what would happen if the climate became cooler and dryer).

3. An ecosystem is a complex environment with many interactions. Make an analogy comparing the parts and events that make an ecosystem work with how some other system works (a school, a hospital, government, etc.).

4. In response to public pressure organized by an animal rights organization, the Iowa legislature proposes to ban the hunting of deer in the state. No more deer hunting. Because of your expertise, you are asked to report to the legislature what you predict will happen to the ecosystems within the state. What changes do you foresee?

5. In his will in 1943, an Iowa corn farmer left his entire farm to the state. His will stated that the farm should be a wildlife reserve, with no hunting, or any commercial use. If you were to take your camera on a field trip through the reserve this weekend, what kinds of organisms would you see to photograph? If you were to return in 20 years, would the reserve look the same?

By the time for the second unit, the two teachers were becoming more loaded and busy with schoolwork. They decided to communicate through electronic mail and they ended up implementing the second unit slightly differently, whereas the third and fourth units were totally different (Appendix B).
Gary.

Gary is an experienced biology teacher with 16 years experience teaching grade ten biology and grade eleven chemistry in his current school. He has a bachelor’s degree in zoology and a master’s degree in education. Gary worked as a manger of a pig-farm for 13 years before he began his teaching career. As stated earlier, Gary planned to team with John to help each other in planning and implementing a series of units from tenth grade biology during the fall semester of the 2003/2004 school academic year, but this did not go as planned (see John for details).

Gary taught 81 grade ten students distributed over four class periods. He was able to implement three units during the first half of the school academic year. The units covered were ecology, cell, and genetics. The cell energy unit was taught following his traditional approach. Therefore, Gary only taught two consecutive units, ecology and cells, using the SWH approach. The big ideas, SWH activities, and conceptual questions for the ecology unit were the same as John. Other unit information is located in Appendix B.

Danielle.

Danielle is an experienced teacher, who has been teaching physical science to ninth graders for 11 years. She holds a bachelors’ degree in extended physical science. Before she became a teacher, she worked in the food service industry for 13 years. A total of 104 students distributed over six class periods participated in the study. Force was the unit Danielle implemented, the same unit implemented during the pilot study last year. She began her implementation of the unit in October for six weeks. Danielle was able to limit the unit big ideas to one main idea—that is, a force may give energy to an object and cause it to start moving, stop moving, or change its direction.
Three SWH activities were used during this unit: friction, spring balance and the force of gravity, and speed and acceleration. The first activity focused on identifying friction and how it affects motion. The second activity was about the relationship between gravity and mass with students adding masses to a spring, relating the stretch of the spring to the pull of gravity, and determining from a constant the actual mass of unknown objects. The third activity was about the motion of a cart moving down a ramp with students trying to identify the components of motion and determining where there is a speeding up or a slowing down.

For the unit assessment test, Danielle included the following conceptual questions:

1. Jason and Tanner were discussing their kite designs and how the kites would fly. Jason claims in his design that all he needed to be concerned about was the force of gravity and its effect on the kite. What do you think?

2. a) Ramona claims that she has a greater acceleration on her bicycle from a rest position to 15 Km/hr for the same time it takes a car to increase its speed from 60-70Km/hr. Is it possible for her to say this? Please explain why.
   b) In the situation described above, if the accelerations are different, can the size (intensity) of the force on the bike and the car be equal? Please explain why.

3. Jessie is writing a story about the planet of Jupiter. In her story she is playing basketball with Michael Jordan. She was absolutely astonished that when he went up for a lay-up, he could only jump 4 inches off the ground. Should she have been so surprised at this event? Why?

Danielle also implemented a second unit, physical properties, following the SWH approach. The second unit implementation (Appendix B) began in January for five weeks.
the physical properties unit collaboratively with Randy, who is one of the new science teachers in her school. Although both teachers agreed on the big idea and the conceptual questions, they ended up implementing different SWH activities.

Billy.

Billy is an experienced teacher who has been involved in classroom teaching for 27 years. He had taught several grade levels from upper elementary to high school level and several disciplines including physics, chemistry, biology and field biology, physical science, earth science, life science, general math, eighth grade math, and health and physical education. In addition to his bachelor's degree in physical education with a minor in science, he has a masters' degree in education administration of secondary education.

Billy has been teaching science and math in his current school for 24 years. He had participated in the SWH pilot study last year and showed great awareness and willingness to cooperate with and learn from the research team. He always indicated that change requires time and provided a nice analogy that the SWH and the pedagogy required were located at one end and his actual teaching practices were located at the other end. Yet he is always looking forward to meeting somewhere in the middle.

Billy decided to participate in the SWH project by implementing two consecutive units: astronomy and machines, work and energy. The units were part of the eighth grade earth science course. The first unit implementation began in late October and lasted for six weeks. Billy taught 139 students distributed over six class periods. His big ideas for the unit were the following:

- What are the differences and similarities among various bodies of a Solar system?
- How do the properties of a star affect its life cycle?
Billy did not ask for feedback regarding the unit big ideas, yet he asked for suggestions for the unit conceptual questions. After negotiating with the project staff the following conceptual questions were generated:

1. Scientists have suggested different names for different bodies within the solar system. Using examples that you can think off, explain how this helps us understand better the solar system

2. Tom said that astronomers use telescopes and other instruments to get information from outer space. Bruce said that using telescopes is enough. Why do you think that Bruce said that? Who do you agree with and why?

3. As a scientist you are constantly seeking answers about our universe. To this point in time, have we learned all we need to know about our universe? What is there more to learn about?

For the first unit, Billy employed two SWH activities to promote learning of the Astronomy unit's big ideas: the first activity was about the differences and similarities of the various bodies of a solar system. The students also focused on creating scaled models of size and distant of the planets of our solar system. The second activity was about the star formation—how a star is born?—in which students were involved in the debate and explanation of the different paths that a star may follow in its life cycle. (See Appendix B for information regarding Billy’s second unit, machines, work and energy).

Matt.

Matt is an experienced science teacher with 21 years experience in teaching middle school science and high school biology. He has a bachelor’s degree in biology science and a master’s degree in education. He has been teaching seventh and eighth grades in his current
school for 14 years. Matt participates in many school extracurricular activities, such as coaching football, wrestling, and track.

This year, Matt participated in the SWH project by implementing a unit on force and motion in seventh grade science, the same unit he implemented during the pilot study. He decided to center his unit on the following big ideas:

- What characteristics do all forces share?
- The effects of friction on an object
- Newton's Laws

Using electronic mail, Matt sent his big ideas for the unit to the project staff to seek suggestions. The researcher explained and emphasized that a big idea is a main concept that a teacher wants his or her students to learn. Knowing Matt’s sensitivity, the researcher tried to open a dialogical communication between Matt and herself and responded to his big ideas as follows:

*The big ideas you wrote seem fine for seventh grade students. However, if we can elaborate on each one to make it more explicit, it would be great! For example, the first BI (the question) usually when we talk about an idea we provide a full sentence(s) instead of a question. If possible we can rephrase it as:

All different types of force are alike in ... and ... (depends on how many characteristics we want to focus upon).

Such an idea implies that although there are different types of force, all have something in common. We can elaborate the same for the other two. The point is, we need to think of what is considered as the core concept and explain it in a full sentence or statement. To know how friction affects an object, makes us think of the
object condition, the kind of friction, (maybe whether friction is good or bad), how it affects our life, etc.

Three SWH activities were used to facilitate understanding of the unit concepts: the egg drop, friction, and lou-vee-air car. The first activity focused on gravity in relation to mass; the second was about friction and motion, and; the third activity was about Newton's laws of motion. His unit assessment test included the following conceptual questions:

1. If you drop a bowling and a baseball ball, both having the same size, at the same time from a 20 m height, which one reaches the ground first? Why?
2. How do you describe the shooting of a basketball by using Newton's laws of motion?

Nick.

Nick is a young teacher with only seven years experience in teaching. He has a bachelor's degree in elementary education, and began his career by teaching science to sixth and seventh grades in his current school. In addition to his bachelor's degree, Nick recently received a master's degree in educational leadership. Nick participates in many school activities, coaching boy's basketball and baseball.

Although Nick felt uncomfortable due to the school changing the science textbook, he decided to contribute to the SWH study by implementing two units: solutions and classification as part of the seventh grade general science. Nick had never taught the solutions unit before. Yet, he did not hesitate to communicate with the teachers and seek suggestions. He also was open in sharing and reflecting on some of the units’ big ideas suggested by the researcher.
The unit implementation began in the middle of November through the end of December 2003. Nick taught 137 students distributed over six class periods. After several discussions with Nick regarding the solutions unit big ideas, he decided on the following:

- Solutions are homogenous mixtures, which implies no chemical reaction happened and physical methods can be used for the separation of its components
- Chromatography is an application of physical separation methods of a solution

Three SWH activities were implemented; the first was the solution/non-solution lab in which students tried to reach a definition of a solution by comparing different types of solutions and non-solutions; the second was the solubility lab in which students chose a variety of different substances to test whether the substance is soluble, not very soluble, or insoluble. The third one is a chromatography activity in which students used filter paper to separate the components of five different black inks.

As for the unit conceptual questions, Nick created three questions that he used along with the question (the first one), that the researcher provided to model the desired type of open-ended question:

1. a) John was arguing with Peter that green color is made out of blue and yellow. He said that he could prove it using paper chromatography. Help John explain to Peter how paper chromatography would prove the components of the green color.
   b) However, Peter is still confused about the logic behind paper chromatography. John said, “It’s like pouring corn syrup and water on a tilted dish surface.” Explain this analogy to Peter.

2. Sally loves canned peaches, but she is on a diet. She wants to know which brand of canned peaches uses the lowest concentration of sugar in the syrup. Unfortunately,
she cannot taste or see any difference. Suppose she had a mass scale, clear straws, food coloring, an electric stove, Pyrex bowls, a thermometer, and a refrigerator. Explain to her (in detail) two or three different ways she could find out which syrup has the lowest concentration of sugar.

3. Suppose you and your family are stranded on a deserted beach and the family car will not start. Beyond the beach is a hot desert. The only source for water is the ocean. There is dry wood on the beach and you have matches, cooking and eating utensils, and a funnel and hose from your car. Explain how you could obtain drinking water.

4. Suppose your younger brother or sister asks you how you can tell the difference between solutions and other types of mixtures. What would you tell him or her?

The second unit, classification, was implemented early in January for five weeks. Nick was much more comfortable with this unit as he implemented it the year before during the pilot study in which he worked with the two other teachers from the high school during the preparation (for more detail see Appendix B).

Cluster Two

The second cluster of teachers is from three districts in western Iowa which was located in area educational agency 13: Riverside, Elk Horn- Kimballton, and Anita school districts, respectively. The science consultant from Area Educational Agency 13 was very supportive and cooperative in recruiting and training educators to help improve science teaching in the school districts. A total of eight teachers participated to the SWH project and all attended three days of professional development workshop similar to the Boone district workshop. Yet, the workshop was held at their school site. Each teacher, however, had different years of taught experience and teaches different grade levels and science discipline.
These teachers were observed using videoconferencing technology (remote-site), as well as having the science consultant from area educational agency 13 or her assistant available whenever possible.

**Riverside Public School District**

From the Riverside district, four science teachers participated the SWH project, one was a male high school teacher and the other three (one male and two females) were middle school science teachers. In this district, students from fifth to eighth grade are considered in middle school level.

**James.**

James is a young teacher with only three and a half years of experience in teaching. For a year and a half, James taught general science to sixth grade students. He joined his current school district two years ago and has taught physical science, chemistry, and advanced chemistry. James has a bachelor’s degree in science education. He was very open to feedback and suggestions and was very keen to be observed. He made it clear that the researcher was welcome to observe any of his sessions simply by using the videoconferencing technology in the specific time he provided. James also told the researcher that he intend to use the SWH approach the whole year.

He participated in the SWH project by implementing one unit—force—as part of tenth grade physics. The implementation began in late November for five weeks. James, who had a total of 35 students, distributed over two class periods, decided to center this unit on one big idea: force is either a push, pull, or twist. With this unit, James began his first experience with the SWH approach. He decided to have a treatment and a control group
design. Thus, 15 students in one-class period were his control and the other 20 students were his treatment.

More than three SWH activities were used for this unit. When James inquired about his students' prior knowledge, he asked them to ask their own questions of what they wanted to learn. Using negotiation, student questions were clustered together. All activities implemented were based on one of the student questions. For example, the first SWH focused on answering the question—why do balls roll up the hill? Another activity was focused on answering the question—how are speed and mass related? As for the unit assessment, James used the following conceptual questions to assess students' conceptual understanding of the unit:

1. Bill and Ted were entering a go-cart race and needed to make a go-cart that applied a force of 110 N. Bill wanted a cart that had a mass of 50 kg and Ted wanted to build a cart that had a mass of 45 kg. Which cart would be the most likely to win the race and why?

2. You are chosen to animate a cartoon strip depicting the space shuttle traveling in a straight line in space. Would you draw the engines fired or not fired? Why did you make that choice?

3. Design a pool table that will allow the pool balls to continuously move after the player breaks the balls at the beginning of the game. Why did you choose each aspect of the design?

Janette.

Janette is an experienced teacher with 25 years experience in teaching language arts, mathematics, science, and social studies to all elementary level. In addition to her bachelor's
degree in elementary education, she has a master’s degree in learning disabilities. Janette joined her current school a decade ago as an English and science teacher for sixth grade.

Janette taught a total of 59 students distributed over three class periods from which 40 students in two class periods were her treatment group and 19 students were in the control group. Janette decided to contribute to the SWH study by implementing a unit on vertebrates, invertebrates, and their adaptations. The implementation began in January for four weeks. She decided to center her unit on the following big ideas:

- Four basic needs of all animals are water, food, oxygen, and protection
- Living organisms have specific adaptations to help them survive in their environment

Three SWH activities were implemented: earthworm movement, a way of life, and joint skeleton lab. In the first activity, students observed the movement of an earthworm on sand paper and on vinyl tile. The second activity was a creative activity in which students created their imaginary animal based on their choice of three adaptations: diet, type of transformation, and special adaptation. In the third SWH activity, students taught how to survive if they had a joint skeleton. The unit assessment test included the following conceptual questions:

1. What are the four basic needs of animals?
2. Name one animal and list the adaptations it has and how those adaptations survive.

Rachel.

Rachel is an experienced teacher with 20 years of experience in teaching math and science to middle and high school graders. She has a bachelor’s degree in mathematics and science. Rachel joined her current school three and a half years ago where she teaches life science to grade seven and earth science to grade eight.
Rachel decided to contribute to the SWH study by implementing a topic, cells in action, as part of the cell unit. The implementation began in late in November and lasted for two weeks. She had a total of 67 student distributed over 3 class periods in which 21 students from one class period served as the control group and 46 students from two class period served as the treatment group. For the preparation of the unit, Rachel communicated with the science consultant from Area Educational Agency 13 and the research staff at Iowa State University. She decided to center her topic on the following big ideas: the movement of particles in the cell as being essential to the cell's survival.

Rachel implemented 3 SWH activities: osmosis in which students used raisins to demonstrate the movement of fluids in and out of the raisins by using different water temperatures and adding sugar or salt; the second activity was about the same concept—osmosis—in which students investigated the movement of fluids using plastic bags to resemble the cell membrane; and the third SWH activity was to promote the idea of cell interaction with environment in which students read the pH of different solutions before and after they exhale in them. Rachel decided to use the following conceptual questions for her unit assessment test:

1. Using pictures, illustrate how different size particles enter and exit a cell. Caption each picture. (Cartoon format is fine.)

2. Write a short article for "Health Monthly" to describe how breathing and exercise are connected to cellular respiration? Attach a diagram with the article

3. Pioneers in North America did not have refrigeration, so they preserved fresh meat by packing it in salt. Explain what process allows the water to leave the meat so that the meat can be preserved.
Danny.

Danny is a young teacher with four years experience in teaching math, reading, science, and spelling at the upper elementary level. He began his teaching career in his current school. He has a bachelor’s degree in elementary education. As his contribution to the SWH study, Danny chose to implement a chapter on plants to fifth grade students. In the beginning, Danny felt confused regarding his role in the classroom during the SWH and being observed, which made him anxious through the first debriefing session, but soon realized the importance of using questioning to generate meaning, which helped him become more comfortable and open during other debriefing sessions.

The plant unit implementation began in the middle of November for a month. Danny taught a total of 40 students distributed equally in two class periods from which he randomly assigned as treatment and a control group. During the unit preparation, Danny worked with an assistant hired by the area educational agency science consultant, who was a science teacher familiar with the SWH approach. Danny decided to center the unit on the following big ideas:

- What does a seed need to germinate?
- What parts of different plants store starch?
- What are the different parts of a flower and how do they work?

Three SWH activities were used in this unit: seed germination; starch in plant; and flower dissecting. The first activity focused on different variables that might affect seed germination in which students carried on different experiments to investigate the effect of light, nutrition, water, temperature; the second was to investigate the starch existence in different plants and different parts of the plant using pH; and the third was about the different
parts of flower in which students dissected flowers to recognize its parts and functions. For the unit assessment, Danny constructed four open-ended questions that required students to directly recall information. After seeking approval from the project staff, he decided to use the following conceptual questions:

1. Completely explain the process that plants use to make food.
2. Plants can adapt in different climates. Describe some examples that you know.
3. You are explaining to Mom that bees carry pollen from plant to plant. How does this help plants reproduce?
4. John and Bill were discussing types of plants. John said that monocot plants are different from dicots. Bill disagrees. Who do you agree with and why?

Anita Public School District

Anita is one of the three shared small districts, which make up CAM: Cumberland, Anita, and Massena. Only two female elementary teachers participated in the SWH project from Anita.

Mandy.

Mandy is an experienced teacher with 24 years of experience in teaching math and science to upper elementary level students. She has a bachelor’s degree in elementary education. Mandy joined the school 15 years ago and currently teaches fourth grade. With one classroom per grade in school, Mandy only taught 21 students. Mandy had communicated electronically with the project staff to seek suggestions regarding the big ideas and the conceptual questions. After negotiations, Mandy appreciated and accepted the detailed suggestions provided. She decided, therefore, to center her unit on the following big ideas:
• Concept of circuits: An electric circuit is a closed system that carries electricity. It needs a source of energy, a conducting media, and an “electric consumer” D-cell; wire and electric bulb are just examples of the elements of a circuit.

• Concept of conductors and insulators: Some materials carry electricity but others do not. We say some materials have electric characteristic and some do not.

• Concept of electric current and magnetic fields: Electric currents produce a magnetic field. The magnetic field of the current is reinforced if the wires that carry the currents are around of a piece of iron, because the magnetic field produced by the iron is added to the magnetic field of the currents (this is called electromagnetism).

Three SWH activities were used to facilitate students understanding of the unit: lighting a bulb, building a circuit, and building a magnetic field. The first activity focused on answering the question: can you light a bulb with a battery, wire, and a bulb? The students worked in groups to accomplish the task and play with variables. The second was targeting the question: what will electricity travel through? The students used a switch with their bulb, wire, and battery to make a circuit. Students experimented with a switch and used different objects to see what would allow electricity to flow through it to complete the circuit. The third activity was to answer the question: can you change the strength of an electromagnet? During this activity students built an electromagnet using a nail. The students explored how they could change the strength using the nail and small washers to test the strength of the magnet. As for the unit assessment test, after negotiation, revision, and feedback with the project staff, the unit assessment test included the following conceptual questions:

1. If the electricity went off and it was getting dark, could you make a light for your family with things that you could find in your home? Your mom said that you cannot
use candles, you can't find any flashlights, and the only things that you have are wire, one battery and a little light bulb. Please make a drawing of how you will get light.

2. The switch broke on the circuit board that you were building. What objects could you use to complete your circuit until you could get the switch fixed? Why did you choose those objects?

3. You make an electromagnet to pick up staples off the floor at school. Your teacher really likes it and wants you to also pick up the paper clips that someone spilled, but it is not strong enough to do that. Can you change your electromagnet so that it can pick them up? How would you do that?

Lucy.

Lucy is an experienced science teacher with 23 years of teaching experience. She developed her teaching experience from teaching science, reading, English, spelling, and mathematics to regular elementary students, specifically kindergarten, first, fifth, and sixth graders. Furthermore, she taught all subjects to students with special needs (special education) in elementary and middle grade levels. Besides her bachelor’s degree in elementary education, Lucy has a master’s degree in education.

Currently, Lucy teaches in a small elementary school with one class per grade level. Lucy has been teaching sixth grade in her current school for three years; yet this year she is teaching fifth grade. This academic school year is her third year experience using the SWH. Her fifth grade class has 28 students.

Lucy is a very active teacher. She has been involved in many regional conferences sharing her experience with the SWH and the results of her students providing samples of
their writing that reflect their high level of thinking. As she taught upper elementary, she managed to combine her language arts teaching with her SWH implementation.

This academic school year, Lucy decided to use the SWH for teaching all science units. She knows when to seek help and never hesitated to ask for suggestions. So far she has implemented three units, astronomy, nutrition, and a unit in physical science—simple machines/work. Below are the big ideas and conceptual questions of each unit

Lucy decided to center the Astronomy unit on five big ideas:

- Our Solar System is in the Milky Way Galaxy.
- Galaxies are large groups of stars, gas, and dust.
- Stars are different in brightness because of distance and size.
- Constellations are star groups with a certain patterns.
- Polaris never changes position in the sky.

The unit assessment test included the following conceptual questions:

1. How does knowing where Polaris is in the night sky help you if you are lost?
2. How does a small star appear to be brighter than a large star in the sky?

Two SWH activities were conducted for the unit. The first activity dealt with apparent brightness issues. The second SWH activity tried to answer the question: “Why does the sky look blue from Earth and black from outer space?” The implementation time of the unit was approximately four weeks. For information of her other two units, please see Appendix B.

**Elk Horn- Kimballton Public School District**

From the Elk Horn- Kimballton district, only two females teaching upper elementary (fourth and fifth grade) participated in the SWH project.
**Rose.**

Rose is an experienced teacher with 13 years of experience teaching all subjects in upper elementary level. She has a bachelor’s degree in elementary education and a master’s degree in education. She joined her current school 11 years ago as an upper elementary teacher.

Rose teaches 21 fourth grade students. She decided to contribute to the SWH study by implementing a unit on magnets. The implementation began late in January for four weeks. The unit was centered on the following big ideas:

- Magnets attract and repel different kinks of materials and other magnets.
- Magnets are surrounded by their magnetic field.
- Magnets are found in the earth.
- Magnets are found in everyday life.
- Magnets have different strength.
- Magnets have north and south poles.

Three SWH activities were implemented in this unit: magnetic strength, magnetic field, and magnets around the house. In the first activity, students investigated the strength of different shapes of magnets in their attempt to answer two questions: What is the strength of the following magnets: Horseshoe, wand, washer, and bar? What do magnets attract? In the magnetic field activity, the students investigated the magnetic field location using iron dust to answer the question: Where is the magnet’s magnetic field? In the third activity, the students investigated different appliances from their house in their attempt to answer: Do the following household appliances contain magnets: Telephone, can opener, coffee pot, remote
control, and pencil sharpener? After reviewing and negotiating with the project staff, Rose included the following conceptual questions in her unit assessment test:

1. Erin wants to hang a piece of paper from the ceiling using two strings with a strong magnet attached to each one. How can she do that? After trying a little, she finds a way in which the paper can be held. Why is there only one way to hold the paper?

2. Explain how a "magna doodle" works?

3. Erin needs to pick up nails from the floor that fell out of the box. She uses a strong magnet and gets a chain of nails. Please explain why she got a chain of nails? What other items will she be able to pick with a strong magnet?

Rodney.

Rodney is a young teacher with only one year of experience in teaching science, social studies, and health to upper elementary and middle grade levels. He has a bachelor’s degree in elementary education and middle school education with a minor in basic science. Rodney joined his current school right after his graduation to begin his teaching career as science, health, and social studies teacher for fifth to eighth graders.

Rodney decided to contribute to the SWH study by implementing a unit on states of matter as part of fifth grade science. He taught 13 students. The implementation began in the middle of February for three weeks. Rodney centered his unit on one big idea: states of matters have different properties. Three SWH activities were implemented during this unit. The first and second SWH activity focused on defining different states of matter guided by the question how do molecules move? In the first activity, the students focused on defining each of the labeled “unknown” substances as a solid, liquid, or gas. In the second activity, the Oobleck, the students investigated one substance that had properties of both liquid and solid.
The third activity attempted to answer the question: Is it possible to trap a gas? Students worked on catching the gas generated from dissolving tablets in a bottle of water using a balloon. The unit assessment test included the following conceptual questions:

1. Compare solids, liquids, and gases in terms of their shapes and volumes.
2. Explain how the motion of particles differs in gases, liquids, and solids.
3. Explain what happens as a puddle dries after a rainstorm.

Cluster Three

The last cluster of teachers presented is also from three different school districts: Central, Des Moines, and Ames. A total of four science teachers participated in the project from the three districts. Except for the male science teacher from the Central district, the three other teachers, of which only one is a female, were familiar with the SWH approach. In fact, they were all classmates who either finished their masters’ degree or were still working on their thesis research project. Therefore, the teacher from central district was the only one who attended the three-day professional development workshop held at Iowa State University campus during the summer along with the Boone district teachers.

Des Moines Public School District

Sondra.

Sondra is science teacher with seven years experience in teaching different science disciplines. She has experience teaching earth science, integrated algebra, and integrated science to middle and high school levels. As she has a bachelor’s degree in secondary education biology, she currently teaches high school general biology to mainly tenth grade students. Sondra is working on her masters’ degree in science education in which she is done with all her required courses and has begun working on her research project.
Sondra joined her current high school as a biology teacher five years ago. She has experience using the SWH from her previous project two years ago when she implemented a unit on cells to her tenth grade students. Her participation in this SWH study will form some of the research for her masters' research. She therefore, decided to implement three consecutive units during the first half of the academic year. However, due to some students' social problems, she was only able to implement two consecutive units, cell and genetics (Appendix B).

Sondra taught 125 students distributed over five class periods. She worked with the science consultant from Area Educational Agency 11 during the unit preparation. For the cell unit, the implementation began in the middle of October for five weeks. The big ideas that Sondra decided to center her unit on were the following:

- The structure and function of cells
- The various types of cells
- Cellular transport

She implemented six activities: the cheek cell lab, the onion cell lab, the diffusion activity, the dialysis tubing activity, the egg lab, and the fish activity. In the first two activities (cheek cell and onion cell labs), the students focused on the differences and similarities between plant and animal cell shapes and structures. The diffusion activity was about determining why food coloring diffused through different media at different rates. The dialysis tubing, egg lab, and fish activities were about the processes of osmosis and diffusion. Students carried out these three investigations to determine how and why osmosis and diffusion take place in cells.
Her unit assessment test for her students' conceptual understanding includes the following conceptual questions:

1. Membranes are important structural features of cells. Describe how membrane structure is related to the transport of materials across a membrane using both active and passive transport.

2. Flasks X, Y, and Z contain solutions with different concentrations of the solute NaCl. Flask X has 0.5% NaCl, flask Y had 0.9% NaCl, and flask Z has 1.5% NaCl. Red blood corpuscles (0.9% NaCl) were placed in each flask, but unfortunately the lab assistant forgot to label the flasks. Explain how you could determine the concentration of NaCl in each of the unknown flasks.

3. Describe the structure of a prokaryotic bacteria cell and explain how it differs in structure from an eukaryotic onion skin cell.

4. Compare and contrast the cells of spinach (plant cell) and the cell of dogs (animal cell). Include at least three comparisons in your answer.

Ames Public School District

Roger.

Roger is an experienced teacher with 18 years of experience teaching several science disciplines, such as life science, earth science, general science, middle school physical science, and high school chemistry to middle and high school grade levels. Besides his bachelor's degree in environmental science, Roger has a master's degree in science education. Roger has been teaching seventh grade biology in his current school for two years. This year, Roger taught 110 students distributed over five class periods. Roger had worked with another
biology teacher from his school, George, and together they were able to implement two consecutive units using the SWH: ecosystem and cell.

Roger had used the SWH before. He knew about it from a conference which he attended about four years ago. He had been using the SWH approach and was working on developing his questioning skills on his own ever since. Roger felt uncomfortable with the researcher being in his classroom observing him. He knew that he was the focus of the observations and was anxious to invite his students to dialogical interactions for the researcher to observe.

Roger and George collaborated together in the preparation of the ecosystem and cell unit using the SWH approach. Both teachers decided on the units’ big ideas, SWH activities, and conceptual questions. The ecosystem unit was taught for seven weeks starting the last week of September and focused on the following big ideas:

- Abiotic and biotic interactions
- Biotic and biotic interactions.
- Biodiversity

Due to school time constraints, George and Roger only implemented two SWH activities during this unit. The first was a field trip to the creek after students had discussed what they knew and expected to see around the creek in which the students were asked to observe living organisms around the creek and collect samples of them. The second activity was to promote the idea of how abiotic and biotic factors affect the life around the creek in which students asked their own question, chose their own variable to investigate, and carried out their inquiry activity. The unit assessment test included the following conceptual questions:
1. The graph below shows a relationship between two groups of animals. Interpret the graph and identify the relationship and the significance of it to the population of each species (graph of hare/fox population trends or moose/wolf population trends).

2. Two organisms occupy the same niche in two similar ecosystems. Over time they eventually cross into each other’s ecosystem. Discuss the potential benefits or problems of each of the organisms occupying the same niche.

3. We have been studying the College creek ecosystem. Compare and contrast the amount, and characteristics of the organism diversity within a regularly mowed field and the creek area we have been investigating.

George.

George is a biology teacher who has been teaching biology for nine years in his current school. During his first teaching year, George taught ninth grade biology. In addition to his bachelor’s degree in science biology, he also has a master’s degree in science education. He taught life science to 128 grade seven students distributed over five class periods.

George is familiar with the SWH approach as he was involved in several small studies in previous years. George and another biology teacher from his school, Roger, had teamed together to implement two consecutive units during the first semester of the academic school year 2003/2004. These units were ecosystem and cell. The big ideas for the ecosystem unit, SWH activities, and the conceptual questions were reported in Roger’s section (for cell unit information see Appendix B).
Central Community School District

Brad.

Brad is a teacher with a bachelor’s of Art degree and six years experience in teaching physics, chemistry, and general science. He joined the current school three years ago to teach physics, chemistry, and junior high science to seventh, eighth, eleventh and twelfth grade students. He participated in the SWH project by implementing a unit on electromagnetism to seventh grade. The implementation began in late November for five weeks. Forty one students distributed over two class periods participated in the study. Twenty students from one class period were in the control group and 21 students were the treatment group. Brad decided to center the electromagnetism unit on the following big ideas:

- **Magnetism**
  - Understand what magnetism is.
  - Describe the interaction between like and unlike magnetic poles.
  - Describe how magnets are created and destroyed.

- **Electromagnetism**
  - Identify characteristics and uses of an electromagnet.

- **Electric Charges**
  - Define and describe static electricity.
  - Describe the interaction of like and unlike electric charges.

- **Electric Circuits**
  - Describe and construct a series circuit.
  - Describe and construct a parallel circuit.
Four activities were implemented during the unit. The first activity included several exploration activities that focused on static electricity, such as balloon on the wall, using a balloon to move a pop can and fur, cloth, glass, and plastic rods with electroscopes. The second activity was to build a working flashlight in which students could use about anything they wanted. The third activity was to construct a machine that could detect real and fake coins. The fourth activity was to construct an electromagnet to transfer paper clips from one paper plate to another.

After agreeing on the provided suggestions, he used the following questions in the unit assessment test:

1. Kelly and some friends were short some money to buy a soda from the machine. Kelly suggested they could use a washer, which is identical to quarter instead of a quarter. However, Billy claimed that it would not work, yet he could not explain why. Other students asked your opinion and explanation as an expert in science. Who would you support and why? Please give a detailed explanation.

2. The power was off for 2 hours due to a car hitting a utility pole near your house. You only have a bulb, batteries and wire. What can you do to get light? Design your own flashlight by drawing a picture and explain with words how your design will work.

3. One afternoon you and your best friend went fishing with your new graphite rod and metal real. You went to the middle of the lake on your boat and dropped anchor. You noticed that the lake was about 4 feet deep. All of a sudden your friend stood up and knocked your fishing pole into the water. How could you retrieve your pole without throwing your best friend in or going after it
yourself by constructing a magnet? You noticed that the boat had all the materials that you needed. Explain why you chose these materials and your design

**Summary**

In summary, the 18 teachers presented in this chapter vary in their didactic teaching experience as well as the highest educational degree obtained. Many teachers taught biology and physical science. Although the units most commonly implemented were cell and genetics in biology, and force and motion in physical science, teachers implemented different SWH activities and assessed student understanding using different conceptual questions. Finally, teachers differed in their level of interactions with the project staff and in their desire for suggestions, feedback, and/or approval in issues related to the preparation of the unit(s).
CHAPTER FIVE

Results

Using a combined approach, qualitative and quantitative, as described in the method chapter, this study focused on assessing the quality of teacher-oriented pedagogy reflected by their implementation of the SWH as an inquiry-based approach. Based on three criteria—dialogical interaction, controlling of knowledge, and unit preparation—developed to distinguish the quality level of teacher implementation of the SWH, a composite ranking score was constructed for each teacher. Evidence from three data collecting techniques—observation, questionnaire, and interview—is illustrated to support each teacher ranking. *Italic* font was used to refer to direct quotes from observation, interview, and questionnaire; however, the first three letters of each data collecting instrument was used as an abbreviation to distinguish the quotation source. Out of the 18 teachers reported in this study, 11 teachers were ranked in level one of implementing student-oriented approach reflected by their SWH implementations, four teachers were ranked in the second level, and only two teachers were ranked in the highest level of implementation.

Due to the existence of several observers, each observer ranked the teacher implementation on a 10-point scale with 1 indicating the lowest and 10 the highest level of implementation. The same scale was used to calculate the percentage of inter-rater reliability with the independent rater. The other two 5-point scales were constructed by the researcher and were not included in the inter reliability ranking. Triangulation of qualitative results generated from different data collecting techniques helped support the ranking of implementation level generated for each teacher and provided a more holistic view of each teacher case study. Furthermore, the quantitative results generated from the statistical
analysis of student outcomes was also triangulated with the qualitative results to provide more evidence to the ranking constructed for few selected teacher case studies.

As a result, this chapter will be organized in two major sections: qualitative results and quantitative results, respectively. The qualitative results are outlined according to each teacher’s quality level of implementation. To be able to highlight similarities and differences in each implementation level, teachers in the low-level ranking scale (1-4) are clustered and reported first; teachers in the middle-level ranking scale (5-7) are clustered together and presented next, and finally; teachers in the high-level ranking scale (8-10) are clustered together and reported last. Teachers in each level are presented in alphabetical order according to their school district first and their name second. Quantitative results are reported for eight case studies of teachers from the three levels of implementation. Results generated from the statistical analyses of selective case studies for the teachers of the untreated control group design will be reported first, followed by the results of analyses of selective case studies for the teachers of one-group pretest-posttest design who satisfied the most control of variables included in interpretation of the student outcomes.

Qualitative Results

Level I Implementation

The 11 teachers in the lowest level of implementation were Mandy from the Anita public school district, Billy, Danielle, Gary, and Matt from the Boone public school district, Brad from the Central Junior/Senior High School district, Rodney and Rose from the Elk Horn- Kimballton public school district, and Danny, Janette, and Rachel from the Riverside public school district. A report of each teacher implementation case was constructed and is presented below including the different ranking scores generated for his/her implementation.
Table 4 includes a summary of the type and number of observations conducted for each teacher in this level.

Table 4. Observational types for Level 1 teachers

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<th>Teacher</th>
<th>District</th>
<th>Observer</th>
<th>Type</th>
<th>Number</th>
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<td>Brad</td>
<td>Central junior/high</td>
<td>The researcher</td>
<td>Videotape</td>
<td>2</td>
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<tr>
<td></td>
<td>public school</td>
<td>Retired teacher</td>
<td>On-site and</td>
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<td>videotape</td>
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<tr>
<td>Rodney</td>
<td>Elk Horn –Kimballton</td>
<td>The researcher</td>
<td>Videotape</td>
<td>3</td>
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<td></td>
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<td>Retired teacher</td>
<td>Videotape</td>
<td>3</td>
</tr>
<tr>
<td>Rose</td>
<td>Elk Horn –Kimballton</td>
<td>The researcher</td>
<td>Videotape</td>
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<td>Retired teacher</td>
<td>Videotape</td>
<td>3</td>
</tr>
<tr>
<td>Danny</td>
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<td>The researcher</td>
<td>Remote-site</td>
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<td></td>
<td></td>
<td>Science consultant 1</td>
<td>On-site</td>
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<td>Janette</td>
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<tr>
<td></td>
<td></td>
<td>Science consultant 1</td>
<td>On-site</td>
<td>3</td>
</tr>
</tbody>
</table>

* Indicates more than three times observation

Mandy.

During the summer of 2003, the Anita public school districted constructed a firewall protection for the internet use; therefore, the researcher was not able to observe Mandy through videoconferencing (remote-observation). Further, due to the lack of a camcorder in her school, Mandy did not provide any videotapes of her SWHs. Mandy had communicated
with the project staff during different phases of her unit preparation and responded to the questionnaire items. The science consultant from Area Educational Agency 13 was only able to observe her one time and based on the observation gave her a 3 on the 10-point scale by providing the following reasoning: “[Mandy] builds on prior knowledge, coaches kids well with questions, encourages writing, challenges their thinking, great energy in the classroom, somewhat traditional in thinking—doesn’t really encourage discourse among kids”.

Due to ethical issues related to research method, therefore, the researcher was not able to construct any ranking score for Mandy.

Billy.

Billy was very eager to be observed. He always invited the on-site observer to his classroom and encouraged the observer to participate in his SWH session. Based on the on-site observer, Billy scored 5 points on the 10-point scale for the following reasons: “Billy had promoted student interaction and the sharing of knowledge. He struggled to interact with students in small group. Also, he struggled within the unit preparation”.

The researcher observed a videotape of an SWH activity from Billy’s first unit (astronomy). The activity was a classroom discussion of student questions and ideas about the solar system. The focus was to group more than 30 questions and ideas according to their similarities into fewer categories. Billy responded to the questionnaire items and was interviewed. The researcher also had a debriefing session with Billy and highlighted a few points related to his role in creating effective interaction with and among students. Based on the observation of Billy’s videotape, the independent rater gave Billy 3-4 points on the 10-point scale for the following reasons: “Billy is very enthusiastic, but most of his questions still ask students for factual knowledge only. It comes across that is what is valued in this class.”
**Dialogical interaction**

Billy showed progress in creating dialogical interaction compared to his implementation during the pilot study. The SWH questions were generated through small and large group discussion. The small group discussion was to construct 5-6 questions about the solar system, whereas the large group discussion evolved around grouping all the small groups' questions and ideas after sharing them on the whiteboard. Billy asked factual questions to students to help group similar ideas together. The discussion pattern was almost similar to initiate-respond-evaluate (IRE) with students responsible for the evaluation instead of the teacher. When disagreement occurred on deciding an issue, Billy did not give his opinion. Rather, he asked the student to vote and followed their decision. Billy informed the researcher that if the student vote was opposing to what is scientifically acceptable, "he would give his vote to solve the disagreement" (Int).

**Controlling of knowledge**

Student questions and ideas (after grouping) were on the board for students to share. Billy took a step forward from last year's implementation by inviting his students to ask questions they wanted to learn about and create their own investigating procedure. Although Billy realized that by "following this format there is no controlling of the students' learning" (Que), he stated that when responding to student's questions his approach was "what I can answer I answer and what I can't, I'll say what do you think" (Int). Further, he added with students' questions "a lot of the times it's mathematically oriented those types of things that I can answer and help them with that part, but with trying to come up with claims and evidence they are on their own" (Int). Billy's understanding was that with the SWH approach he should not give students answers or knowledge yet this was only related to the unit
concepts. Thus, his role as a “motivator” (Que) was targeted concepts of the unit. When describing his role in the SWH Billy stated, “they [students] are driving the bus and I am along for the ride. If you get lost I have Triple A and I can get us back on track” (Que) compared to

“get on the big yellow bus. I am the bus driver, and away we go... You may fall off the bus but have patience I will come back and pick you up after I get most of you to the first stop” (Que) for the traditional approach.

**Unit preparation**

Billy perceived a difference between the traditional unit preparation and the SWH. “The preparation is limited at the beginning because the big ideas are driven by the student discussion and debate. The materials to be used may or may not be in storage” (Que). Billy admitted that connecting students’ questions and ideas of the unit to the big ideas was not an easy task for him: “that’s not easy. It’s not easy for me how to get their questions to relate with the three big ideas that we [Billy and the project staff] came up with” (Int).

In general, Billy’s implementation of the SWH illustrated a few elements of the inquiry-based approach reflected of inviting students to ask their own questions and design their investigating procedure. Although he was dispensing information to students upon asking, he believed that his role has changed from telling to “motivating” (Int). Working on his new role, he promoted limited interaction among students and tried to encompass their prior knowledge. Yet, he asked factual questions to ensure students’ learning of the new unit. Billy was aware that changes he made to his instructional practice indicated a small shift away from teacher-oriented approach. In fact, he articulated that on a continuum spectrum, he falls on the opposite end of what the SWH required him to do. Further, he defined few
areas that he needed to work on. Billy’s scores from the three ranking scales are illustrated in Table 5.

Table 5. Billy ranking scores

<table>
<thead>
<tr>
<th>Ranking scale</th>
<th>Interaction scale</th>
<th>Controlling scale</th>
<th>Preparation scale</th>
<th>Composite</th>
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</thead>
<tbody>
<tr>
<td>Score</td>
<td>4/10</td>
<td>2/5</td>
<td>2/5</td>
<td>8/20</td>
</tr>
</tbody>
</table>

Danielle.

The researcher was only able to observe Danielle once during her second unit implementation. Although the researcher did not observe the whole period, she noticed that Danielle’s implementation had not developed compared to last year’s implementation during the pilot study. Danielle was handing back a student quiz on matter and temperature, which was basically constructed of recall questions of the fill-in-blank, match, and multiple-choice question types. The discussion was about student responses on the quiz. Danielle also handed out a passage for reading and began a discussion of the goal of reading or how to define the big idea. The on-site observer (a colleague researcher) observed Danielle many times during her first and second units. He reported that there was not much dialogical interaction in her classroom. Further, many times during the first unit implementation Danielle reported her dissatisfaction with the teaching approach. Although she did not agree to be interviewed, she responded to only 5 items from 12 questionnaire items. The on-site observer gave Danielle 3 points on the 10-point scale supporting his score with the following reasons: “Danielle struggled to initiate a discussion with her students whether in small or large group. She could not believe that student can learn from inquiry without knowing the science vocabulary first. She had a problem with classroom management”. The independent rater also scored
Danielle’s implementation of the SWH as 2 points on the 10-point scale for the following reasons: “Danielle dispensed information and has poor questioning skills. She struggled with classroom management. Activities although open inquiry, she failed to connect to the big idea.”

**Dialogical interaction**

Danielle did not believe that ninth grades students could ask questions of each other or be involved in a learning discussion. So, creating dialogical interaction was difficult for her;

“students really resisted thinking on their own. This group does not work together in teams and were resistant to the work involved writing & reading. Even with detailed analysis, peer SWH evaluations & self-evaluations not much interest in improvement POOR LISTENING SKILLS ALSO” (Que).

However, the on-site observer reported that when a student asked a question Danielle either chose to give a direct answer or ignore the question, even when students said, “I don’t agree with you”, she just ignored the comment and continued talking about different things (Obs). The observer also noticed that one or two groups were not on task, but Danielle did nothing to bring them back in or tried to initiate a discussion about the activity with them. The researcher, during her only observation, noticed that Danielle’s questions were short-answer questions, for example, what is the main idea? What “are some strategies to define them? What does a main idea look like?” (Obs). Further, although Danielle tried not to evaluate her student response her non-verbal actions clearly indicated her dissatisfaction with the response she got.
Controlling of knowledge

Presenting information to students clearly reflected her controlling of knowledge. She confused behavioral discipline with controlling learning, thus the SWH was difficult to implement for the following reason: “There seems to be a greater resentment produced than a feeling of success. Freshmen still need to have a certain amount of structure and guidance” (Que). Her students were not motivated to respond to her rhetorical (for grade nine) question. Danielle was writing all their response on the whiteboard. The on-site observer informed the researcher that Danielle did not provide the investigation procedure yet did not create a discussion at the beginning of the SWH. In her response to the value of the SWH, Danielle agreed that, “there is a tremendous value. Student centered, group opportunities for discussion, student owned ideas/concepts” (Que). The response would indicate that her understanding of the value of the SWH approach is not match by her actions.

Unit preparation

As stated before, the first unit Danielle implemented was the same unit implemented during the pilot study in which she had had help with defining the big idea and choosing the SWH activities. The second unit preparation was done collaboratively with another teacher from her school. For both units, the choice of the big idea and the construction of the conceptual questions were appropriate; however, Danielle was working with the project staff during the preparation and had received lots of help. The fact that students’ prior knowledge was not considered all the time reflected her choice to not respond to student questions.

In general, Danielle resisted admitting that she failed to involve her students in dialogical discussion. She definitely had a class management problem. She blamed the students for not interacting appropriately with each other and not being able to think for
themselves, to cover up her poor questioning and understanding of the SWH. Danielle did not feel comfortable with the project staff around her classroom. In fact, she felt threatened by being observed and provided with feedback, which might be explained by her very slow shift away from the traditional approach. Danielle’s scores from the three ranking scales are illustrated in Table 6.

Table 6. Danielle ranking scores

<table>
<thead>
<tr>
<th>Ranking scale</th>
<th>Interaction scale</th>
<th>Controlling scale</th>
<th>Preparation scale</th>
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<td>1/5</td>
<td>1/5</td>
<td>4/20</td>
</tr>
</tbody>
</table>

*Gary.*

The researcher was not able to observe Gary on-site, but she observed a videotape of one of his SWH sessions within the cell unit. The activity was about similarities and differences between plant and animal cells. The colleague on-site observer was able to observe many of Gary’s SWH sessions. He reported that Gary did not show much enthusiasm and there was not much dialogical interaction with or among the students in his classroom. Therefore he gave him 4-5 points on the 10-point scale for the following reasons: “Gary had good theoretical understanding, but could not translate into practice. The connection between activity and content was missing. He talked too much. His class discussion was better than small group discussion. He listened to classroom discussion”.

Gary had responded to the questionnaire items and participated in the interview. The independent rater gave Gary 3-4 on the 10-point scale due to the following reasoning: “Gary was sitting most of the class and more mechanical in his implementation. The students were engaged however”.
**Dialogical interaction**

Observation of Gary's videotaped session indicated student-student interaction. Students were sharing, discussing, and writing on the whiteboard. The teacher sat in the back of the classroom after directing the students to fill in Venn diagram facts they knew about cells. The few times he decided to participate in the discussion, he mostly asked short-answer questions: “what do we need CO₂ for? What process is plant doing? What do we use O₂ for?” (Obs). He was aware that he needed “to monitor student discussions and small group activities to keep students on task” (Que) yet only when discussing claims and evidence in small group; therefore, when asked how would he do this, Gary stated that he “might walk around and just see if they are talking about claims of evidence or their social life” (Int). On the other hand, Gary did not understand the role of initiating student-student interaction in directing student thinking. “No, should I have?” (Int) was his response when asked if he had approached a small group while working on the investigating procedure and asked questions.

**Controlling of knowledge**

Gary did not see himself as controlling student learning. Yet, he admitted that he was “still learning to switch off the answer machine” further he was “learning the art of questioning” (Que). The on site observer reported that students were not afraid to interact with each other and to be involved in a discussion. The inquiry activities were either structured or guided types. Students were able to take control of the whiteboard through the discussion; however, Gary did not participate or monitor the discussion. The metaphor that Gary chose to describe his role within the SWH—*parent of a teenager*—reflected his understanding of student-oriented approach “they want to go, go, go. But they don't want to clean up their thinking or improve their skills. It should be fun. No chores, please” (Que).
Unit preparation

Gary’s preparations of the units reflected his understanding of the content. The activities were related to the big ideas and his conceptual questions were targeting concepts within context from student life. However, when asked for his reasoning for not using the SWH with the cell energy unit, he responded “because it was one chapter long ... the other ones were many three or four chapters long” (Int). Further, when asked if this unit was considered as part of the cell unit, he agreed and admitted “I’ve never thought of it” (Int).

In summary, Gary’s epistemological belief was not compatible with his classroom practice. He knew that his role was not to dispense information, but he struggled to “switch off the answering machine.” (Int). Further, he needed to work on his questioning skill to ask more open-ended questions to promote student negotiation. Although he believed that students could think for themselves and be involved in a discussion, he could not see his role as a facilitator of a discussion. His view of student-oriented was clearly reflected of avoiding not only participating in student-student discussion, but also directing (initiating) student thinking. Gary’s scores from the three ranking scales are illustrated in Table 7.

Table 7. Gary ranking scores

<table>
<thead>
<tr>
<th>Ranking scale</th>
<th>Interaction scale</th>
<th>Controlling scale</th>
<th>Preparation scale</th>
<th>Composite</th>
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</thead>
<tbody>
<tr>
<td>Score</td>
<td>4/10</td>
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<td>3/5</td>
<td>9/20</td>
</tr>
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</table>

Matt.

The researcher on-site observed Matt twice, but not for the whole period. Matt responded to the questionnaire items and agreed to be interviewed. The first time he was observed was during the follow up discussion to the egg drop activity. The second time was
about measuring distance, which was not an SWH activity, but Matt noticed that his students could not use the metric system to measure length, so they were engaging in activities like hanging weight to spring and measure the distance and sliding a bottle over a ramp and measure the distance. His on-site observer had ranked him as 4-5 points on the 10-point scale for the following reasoning: “He is sharing ideas on the board. Matt is keen to learn and always look for strategies to help his implementation. Has good classroom management”.

The independent rater also ranked Matt as 4 on the 10 point scale providing the following reasons:

“Matt showed progress from where he was last year. He still needs to work on his questioning skill. He began to share all student ideas on the board, yet he failed to create dialogical interaction with all students. He interacts with one student at the time. He needs to interact with small groups”.

**Dialogical interaction**

Matt did not go around to all groups. Most of the time Matt was observed, he was moving near the whiteboard in front of the room. His students were engaged and on task. He asked few questions to students as a group. He felt that he needed to develop “patience” (Que) and explained that, “I personally get frustrated with getting through some of the parts maybe because I’m new at it. Also the students, when we were writing the SWH, were not putting more thoughts into the data collected” (Int).

**Controlling of knowledge**

Matt struggled to not provide information. As he stated, he needed to develop patient “to wait for students to understand the approach and see connections between data and their claim” (Int). He valued the SWH because “it makes students more accountable for
information" (Int). Matt described his controlling of the knowledge in his classroom as "steering them [students] towards ideas or concepts. Trying to sift through correct and incorrect information that they share" (Int).

Unit preparation

Matt struggled with defining his big ideas. He stated them in an abstract form as concepts. His activities were related to his big ideas. All student ideas and questions about the unit were discussed in class; however, he tried to limit them to few ideas, so that they would match his. Matt knew what his role is to relate the activity to the big idea, and suggested he was using

"probably more questioning and more having students reflect on things that they have learned and we keep the big Idea on the board so that they can always point back to. That’s what were trying to get back to and what we try to understand" (Int).

In general, Matt showed progress from where he was last year. The ideas were put to share for all students and were left on the whiteboard. He needed to improve his questioning skill and work on strategies to promote dialogical interaction. Matt’s scores from the three ranking scales are illustrated in Table 8.

Table 8. Matt ranking sores

<table>
<thead>
<tr>
<th>Ranking scale</th>
<th>Interaction scale</th>
<th>Controlling scale</th>
<th>Preparation scale</th>
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<tbody>
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<td>4/10</td>
<td>2/5</td>
<td>2/5</td>
<td>8/20</td>
</tr>
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</table>

Brad.

Due to the lack of the appropriate apparatus for the remote-site observation, the researcher observed two videotapes from two SWH activities. Brad agreed to be interviewed
and responded to the questionnaire items. After the first videotape observation, the researcher had a debriefing phone session with Brad in which a number of points were discussed (Appendix C). His on-site observer was present for two SWH observations and gave him 2-3 points on the 10-point scale for the following reasoning:

"Classroom discipline and students being on task is an issue. My on site observation makes me believe that this is an area that needs to be addressed before a meaningful SWH can happen. In second class, at least student ideas and questions were put on the board as public by students. Teacher is still giving answers and clarifying student ideas".

**Dialogical interaction**

Observations of two SWH activities indicated his struggle to initiate scientific dialogue with his students or among students themselves. The researcher rarely observed any interactions between Brad and his students while working on the activity. Some of the students were not always on task and he did nothing to bring them back to the activity. Brad misunderstood his role within the SWH, as he stated,

"it is more like sitting back let the students share ideas, and with the traditional I mostly did that my self, I let them share ideas but I didn't let them go off on a different tangent it was more controlled" (Int).

When asked about his role he stated, "my role has changed. The students are coming up with the ideas and solutions to the problems and are not relying on information coming from me" (Que).
**Controlling of knowledge**

Brad’s understanding of not controlling student knowledge was to take the back seat. He did not perceive the benefit of asking questions to focus student thinking. As he confirmed his role

"in an SWH one person shoots an idea then another student either says it in another way and added to it and it just went back and forth and I am just sitting in the back listening maybe I paraphrase an idea so they can write it on the board easier, but mostly they are just writing ideas on the board" (Int).

His SWHs were guided inquiry type and directly related to his big ideas and conceptual questions. Nevertheless, constructing conceptual questions to be directly related to the SWH activities or, the other way around, finding activities that insured student response on the conceptual questions pointed toward traditional teaching approach.

**Unit preparation**

He did not see a difference in the unit preparation as he stated, “it’s about the same. I did the same labs, but did them in a different way” (Que). He was guided by “the standards and benchmarks” in defining his unit big ideas. Students’ prior knowledge, was also used in planning because “some of the students talked a lot about this already, so we might mention the thing, but not talks about it a lot, cause they had it before or I thought they understood it already” (Int). His conceptual questions were targeting his SWH activities.

In summary, although Brad was able to articulate the desired role of a teacher when using the SWH, his implementation reflected a different role. He did not interact with his students while they were investigating and most of his questions were factual. Although Brad did not perceive a difference in the unit preparation, he was aware that his role should be
different between the two approaches—student-oriented and teacher—oriented. Nevertheless, he chose to interpret this difference as refraining from being involved in student discussion.

Brad’s scores from the three ranking scales are illustrated in Table 9.

Table 9. Brad ranking scores

<table>
<thead>
<tr>
<th>Ranking scale</th>
<th>Interaction scale</th>
<th>Controlling scale</th>
<th>Preparation scale</th>
<th>Composite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Score</td>
<td>3/10</td>
<td>1/5</td>
<td>1/5</td>
<td>5/20</td>
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</table>

Rodney.

Rodney implemented two SWH activities in two consecutive class periods, each was 30 minutes long. The third SWH activity was implemented during another class period the following week. The researcher was not able to remote-site observe his SWHs due to reasons similar to Rose. Instead, she observed two videotapes of his three SWH sessions. The tapes were sent after finishing the unit implementation. Consequently, the feedback (Appendix C) sent to Rodney did not help improve his implementation. Rodney did not respond to the questionnaire items nor did he agree to be interviewed. The scores generated were primarily based on observation. The on-site observer, the science consultant from Area Educational Agency 13, observed only his first and second SWH implementation and had a debriefing session with him afterward. A copy of her field notes, including her suggestions (Appendix C), was sent electronically to the researcher. Taking into account that this year is Rodney’s first academic year of teaching, the on-site observer gave him 2 points on a 10-point scale for including few components of inquiry. The independent rater, based on observing Rodney’s videotape, ranked him as 4-5 on the 10-point scale for the following reasons:
"Teacher gave questions for students to test. By him defining what the students were to find out, they immediately lost ownership. The up side was his just giving them the materials and telling them to test in anyway they wanted the materials. The implication was that they already know the definition for the three states of matter, so we'll just treat against known definitions and see if we can put the items under the correct headings. Rodney did do a good job of moving from group to group, and kept student interest by being involved in individual groups. The issue is who decided what to test? Who decided the questions?"

**Dialogical interaction**

The beginning questions were provided to the students. No discussion was held for other questions that students might have or the testing procedures to be used. While students were working in small groups of two, Rodney was going around making sure they were on task; however, he did not initiate any dialogue with or among students. Student testing was merely observing and touching items. Only once within the Oobleck activity—the second SWH activity—a student asked: "what is it?" And the teacher responded "I don’t know you tell me" (Obs). The interaction ended at this point without any further questioning. At the end of the period, Rodney had less than two minutes for large group discussion in which he asked a few short-answer questions to summarize the SWH activity. This limited interaction replaced the sharing of claims and evidence. Observation of the videotapes indicated that no discussion took place to relate the activity to the beginning question. Further, there was no connection of the activity to the big ideas.
Controlling of knowledge

Rodney was in control of the few discussions. Further, he practiced strict student behavior management in which he assigned who gets what (materials) and when during the SWH activity. Observations of three SWH activities lacked the component of public knowledge sharing. There were no signs of using the whiteboard to share the activity focus or the meaning generated. The third activity was a very structured activity in which students were to place a balloon on the top of a water bottle after he dropped in two dissolving tablets to catch the raising gas.

Unit preparation

Rodney’s big ideas of the unit focused on defining different states of matter. He confused the unit’s big ideas with the beginning questions of the SWH activity. The following was an electronic mail Rodney sent to the project staff, which clearly illustrated his confusion

"AEA 13 [science consultant] told me to e-mail you my "big ideas". The question I want them to answer is name each of the labeled "unknowns" as either a solid, liquid, or gas. Use the other materials in front of you to test".

After receiving feedback from the project staff on his big idea (beginning question of the activity), he merely changed the activity question to how do molecules move? Leaving the activity as it was. This reflected his struggle in teaching from this approach.

In general, Rodney’s implementation reflected more teacher-oriented than student-oriented instruction. His choice of the activities was not challenging enough for the students. There was evidence of student-student interaction; however, it was limited. The class discussion was teacher directed in which students answered a few factual questions.
Rodney's dissatisfaction with the SWH was reflected in his limited communication with the project staff. Rodney's scores from the three ranking scales are illustrated in Table 10.

Table 10. Rodney ranking scores

<table>
<thead>
<tr>
<th>Ranking scale</th>
<th>Interaction scale</th>
<th>Controlling scale</th>
<th>Preparation scale</th>
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<td>1/5</td>
<td>1/5</td>
<td>3/20</td>
</tr>
</tbody>
</table>

*Rose.*

Due to the firewall protection that the school created during the summer to protect illegitimate use of the school server, the researcher was not able to use the remote-site observation technique. Instead, the researcher observed three videotapes including Rose's three SWH activities, and collected all the feedback given to her using electronic mail (Appendix C). Although Rose appreciated the suggestions provided, by the time she received them it was too late to help her during the next SWH implementation.

The on-site observer, the science consultant from Area Educational Agency 13, only observed Rose's first SWH implementation and had a debriefing session with her afterward. A copy of the field notes, including suggestions, was sent electronically to the researcher (Appendix C). Being aware of Rose's obsession for controlling student behavior, the science consultant thought that Rose underwent a huge change by allowing her students to interact with each other to create their own investigation procedure. Thus, based on her on-site observation of Rose's first SWH, she gave her 5 points on a 10-point scale. She supported her ranking stating that, "*Rose builds on [student] prior knowledge, coaches kids well with questions, encourages [their] writing, challenges their thinking, [and there is a] great energy in the classroom*."

Indeed, Rose’s first SWH included a discussion of the importance of controlling variables during testing in which Rose drew an example from everyday life—the oven temperature needed to bake a cake. The independent rater gave Rose 4 points on the 10-point scale, based on his observations of Rose’s three SWH activities. He supported his ranking with the following:

“Looked like questions came from a worksheet?! She tended to say very good in response to students answers thus cutting off further ideas. There was some evidence of good student-to-student work in groups. She did miss an opportunity to address some student ideas and remained focused on the worksheet question that was bothersome”.

**Dialogical interaction**

Rose asked factual questions to her students and rarely asked why and/or how questions. There was no evidence of dialogical interaction in her classroom. When asked for her reasoning of giving the beginning question of the SWH activities and not promoting any discussion of other beginning questions that her students might have, Rose responded that,

“I was worried they weren’t going to ask the questions that I wanted them to ask. I am probably wrong, but I wasn’t so sure that they would come up with questions. With that, how do I know if I have the stuff that they are going to want to ask the questions about?” (Int).

During the activity, few interactions were initiated with the students. When an interaction was initiated, it was mainly to provide approval for testing procedures and/or to keep track of the time. “Okay” and “yes” were some phrases Rose used to confirm students’ responses. The
sharing of claims and evidence also did not include any dialogical interaction. All discussions were between Rose and one student at a time.

**Controlling of the knowledge**

Although Rose did not feel in control of student learning, she described her students with the SWH as "free birds, tackling the problems as they believe will answer their questions quite often they are different from where I would take them!" (Que). Providing the beginning question of each SWH activity and controlling the discussion were pointing in the opposite direction. All discussions were between Rose and one student each time. A clear example of her controlling students' knowledge happened during the sharing of claims and evidence in the third activity when a student claimed that there is a magnet in the telephone handset located on the listening side and while he was about to provide his evidence Rose quickly reminded him stating that, "we are focusing on whether the house appliance includes magnet or not. We are not looking for its location" (Obs). Rose admitted her struggle when using the SWH due to not understanding her role stating that, "I wasn’t quite sure I was doing it correctly" (Qus); however, she realized that, "I am not spitting out information I am drawing the ideas out of the student" (Qus). Further, she knew that she needed to improve her questioning skill. She stated,

"when they [students] were doing the testing and the observing I knew I should not be telling or giving them answers, but I struggled with asking questions. How much can I give them to lead them and how much should I hide" (Int).
**Unit preparation**

Rose informed the researcher that she "had not taught magnets at all ever and it is not in our science textbook" (Int). The choice of the activities was adequate to promote the big ideas. Yet, there was no evidence of relating the big ideas to each other. Further, Rose perceived the SWH merely as a different way of doing hands-on activities in which students can generate their own testing procedure. She stated "I intentionally looked for ways that I could do SWH with. I had to be sure that we could pull an SWH lab from it" (Que); to be sure that students can generate their own testing procedures.

In summary, Rose's implementation was influenced by her obsession to control student behavior, as she described herself "I'm a control freak" (Int). By sustaining student behavior she did not provide enough time for student discussion. By the end of the unit’s implementation, Rose thought that the second activity about the magnetic field "was a flop" (Int); however, she could not define what went wrong. She relied more on telling students information rather than engage them in a discussion. Rose's scores on the three ranking scales are illustrated in Table 11.

Table 11. Rose ranking scores

<table>
<thead>
<tr>
<th>Ranking scale</th>
<th>Interaction scale</th>
<th>Controlling scale</th>
<th>Preparation scale</th>
<th>Composite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Score</td>
<td>3/10</td>
<td>1/5</td>
<td>2/5</td>
<td>6/20</td>
</tr>
</tbody>
</table>

**Danny.**

The researcher was able to observe Danny three times using remote-site observation. Further, she had phone debriefing sessions with him and was able to provide feedback to him before the next observation, which helped improve his implementation. Although he did not
agree to be interviewed, he responded to the questionnaire items. The scores generated for
Danny, therefore, were based on the observation and the questionnaire. Danny's on-site
observer—science consultant from Area Educational Agency 13—gave him 5 points on the
10-points scale based on her observation of the first SWH and provided the following reasons:
“[Danny] builds on [students'] prior knowledge, coaches kids well with questions,
encourages [their] writing, [and] challenges their thinking”. Danny did not provide a
videotape of any of his SWHs for the independent rater. Due to the high inter-rater reliability
(81.25%); the researcher was able to extrapolate her ranking for Danny.

**Dialogical interaction**

Danny promoted some student-student interaction within his first SWH activity which
encouraged students to discuss in small groups and construct their questions related to: what
do seeds need to germinate? He further directed them to create their own investigation. There
was no discussion regarding student questions and the testing procedures. By going around,
Danny merely checked each group’s beginning question and testing procedure. His questions
were a mixture of short and extended answer questions. The second observation included a
large group discussion of student questions, however, the discussion was teacher directed. By
the second activity, Danny began to perceive the value of challenging student thinking
through questioning and felt the need to improve “student credibility for their own work”
(Quo).

**Controlling of the knowledge**

Although Danny was in control of all classroom discussions, observation of his
classroom revealed students comfortably sharing their ideas and results. The discussion of
claims and evidence was controlled by the teacher rather than mediated by him. Danny asked
each group to share their claim and evidence, initiated questions for them, and rephrased student responses before asking others of their opinion. Whenever a disagreement occurred, Danny gave his opinion as a way to settle the problem. When asked about his feeling of controlling the knowledge, he stated, "I don't feel knowledgeable in this area to comment" (Que). Further, he did not provide a metaphor to describe his role when using the SWH.

**Unit preparation**

Danny's choice of activities was appropriate for promoting his big ideas. There was evidence that Danny did not understand teaching for the big ideas; therefore, his choice of a topic to participate to the SWH project was influenced by finding a chapter that included three activities. Although Danny felt a difference in the unit preparation, he attributed it to student responsibility; "students run the groups, instead of teacher dominated approach" (Que). Further, Danny's conceptual questions were a form of direct recall or extended answers.

In summary, in the beginning, Danny's implementation reflected his struggle with the approach. He did not know if he was doing what he was supposed to do. The debriefing session helped improve his implementation and his comfort level with the approach. He reported that using questioning within small group discussion helped him understand his role. His SWHs challenged student thinking and encouraged interaction. Large group discussions, however, were teacher directed. Danny's scores from the three ranking scales are illustrated in Table 12.

<table>
<thead>
<tr>
<th>Ranking scale</th>
<th>Interaction scale</th>
<th>Controlling scale</th>
<th>Preparation scale</th>
<th>Composite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Score</td>
<td>4/10</td>
<td>2/5</td>
<td>1/5</td>
<td>7/20</td>
</tr>
</tbody>
</table>
Janette.

Janette did not agree to remote-site observation or videotaping her SWH sessions. She responded to the questionnaire items but did not agree to be interviewed. The AEA 13 science consultant was invited only once to observe her SWH. Based on one observation, she gave her 3 points on the 10-point scale for the following reasons: “[Janette] builds on prior knowledge, coaches kids well with questions, encourages writing, challenges their thinking, great energy in the classroom, somewhat traditional in thinking—doesn’t really encourage discourse among kids”. Due to ethical issues, the researcher was not able to generate any score for Janette.

Rachel.

Using a remote-site, the researcher was able to observe two class periods of Rachel implementing her SWHs. The third attempt to observe failed after 10 minutes due to technical problems. Each activity was implemented during two consecutive days. Unfortunately, the researcher was not able to have a debriefing session with Rachel due to her class schedule, but was able to send written feedback to her before the next session; however, the short time of implementation hindered the desired benefit. Based on observation of two SWH activities, the on-site observer gave Rachel 2 points on the 10-points scale for the following reasons: “[Rachel was] pretty traditional, didn't change her teaching style much. [Her] investigations were pretty directed. She did pretty well with questioning and waiting to confirm with textbook”.

Rachel’s case was similar to Danny in which she responded to the questionnaire items, but did not agree to be interviewed. In addition, she did not provide a videotape of any of her
SWHs; thus, the independent rater could not rate her implementation. The researcher extrapolated her ranking for Rachel.

**Dialogical interaction**

Rachel provided information to students rather than engaging them in a discussion. Her implementation reflected her struggle with questioning and her ability to initiate a discussion among her students. There was evidence of a dialogical interaction with the students or among them. Rachel provided answers for her factual questions if her students did not respond. Few interactions occurred in which she asked short-answer questions. Further, she began her period by telling the students all information that she assumed they knew when covering the cell chapter. The discussion of claims and evidence was during another period, which the researcher was not invited to observe.

**Controlling of knowledge**

The teacher provided the beginning questions for the activity and left the testing procedure to the students. The goal of the activity was to confirm information or concepts already provided to students. Rachel, who continually rephrased student responses to confirm the knowledge, was aware that she was in control with respect to “present[ing] materials or [an] opportunity to see other experts writing” (Que), but was not in control with respect to student learning.

**Unit preparation**

The choice of activities was adequate and related to the big idea in which students learned about osmosis and diffusion. In preparing for the SWH unit “more knowledge and preparation is needed to be able to present each SWH” (Que). During the third SWH, the
teacher constructed the activity on measuring pH of different solutions; however, students lack prior knowledge about the pH concept.

In general, Rachel’s implementation was considered more didactic in that she dispensed information to students and consideration of student’s prior knowledge was not always undertaken. Essential elements of constructivism were missing from her implementation; for example, facilitating student learning through promoting interactions and allowing more time for student to construct their knowledge. Rachel’s scores from the three ranking scales are illustrated in Table 13.

<table>
<thead>
<tr>
<th>Table 13. Rachel ranking sores</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ranking scale</td>
</tr>
<tr>
<td>Score</td>
</tr>
</tbody>
</table>

Summary

Teachers in this level practiced more teacher-oriented than student-oriented approaches; most of the teacher activities recommended by the SWH teacher template were neglected. Teachers asked more factual questions of the students and the classroom interaction observed followed the IRE form (Lemke, 1990). Teachers were struggling to apply the desired role as facilitator of learning or a debate mediator. Further, the inquiry tasks were either structured or guided inquiries.

Level II Implementation

The five teachers in this level of implementation were George and Roger from the Ames public school district, Nick was from the Boone public school district, Sondra was from the Des Moines public school district, and James was from the Riverside public school.
district. A report of each teacher implementation case study is presented below including the different ranking scores constructed for his/her implementation case. Table 14 includes a summary of the type and number of observations conducted for each teacher in this level.

Table 14. Observational Types for Level II teachers

<table>
<thead>
<tr>
<th>Teacher</th>
<th>District</th>
<th>Observer</th>
<th>Type</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>George</td>
<td>Ames public school</td>
<td>The researcher</td>
<td>On-site</td>
<td>3+</td>
</tr>
<tr>
<td>Roger</td>
<td>Ames public school</td>
<td>The researcher</td>
<td>On-site</td>
<td>3+</td>
</tr>
<tr>
<td>Nick</td>
<td>Boone public school</td>
<td>The researcher</td>
<td>Videotape</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Graduate student</td>
<td>On-site</td>
<td>3+</td>
<td></td>
</tr>
<tr>
<td>Sondra</td>
<td>Des Moines public school</td>
<td>The researcher</td>
<td>Videotape</td>
<td>2</td>
</tr>
<tr>
<td>James</td>
<td>Riverside public school</td>
<td>The researcher</td>
<td>Remote-site</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Science consultant 1</td>
<td>On-site</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

*+ indicates more than three times observation*

*George.*

The researcher was able to be an on-site observer for Gene's SWH implementation. George implemented the first unit, ecosystem, following the SWH for the first time. As a result, his implementation reflected a struggle with involving students in dialogical discussion. During the debriefing session (Appendix C) George attributed his struggle to students' readiness to understand the concepts involved. He provided two videotapes of his SWH, one from each unit implemented. Although he responded to the questionnaire items, the researcher did not interview him. Another researcher had an open conversation regarding the SWH implementation (unstructured interview) with George during the second SWH unit implementation. His responses were used in this study. The independent rater, based on observing the SWH session of the cell unit, scored George's implementation between 6 and 7 points on the 10-point scale, providing the following reasons:
“George asked students to see if they could see any patterns from observations. Students’ labs were made public. George was interested in his students having working definitions about diffusion and semi-permeable membrane. George kept assessing students’ prior knowledge and tying that to the big ideas. Group discussions were going on, and there was a conscious effort to help students make connections between what they were doing and past experiences”

**Dialogical interaction**

George’s familiarity with the SWH was revealed through his questioning skills. He asked open-ended question of his students and always required further elaboration of student responses. Nevertheless, the discussions were mostly between George and one student at a time. The researcher noticed that George had missed many opportunities to create dialogical interaction in his classroom and repeated student responses before asking another student for his/her opinion. However, he never answered students’ questions and always appeared ready to respond by asking additional questions. He also always encouraged student-student interaction in small groups. One drawback was that during small group discussion George used phrases such as “write this down or good” (Obs). George was aware of his role as a science teacher when he stated, “I see my role as probably more facilitating their learning instead of teaching them in the traditional sense of teaching” (Int).

**Controlling of knowledge**

George’s implementation clearly reflected his epistemological belief. His activities were open inquires which allowed students to ask their questions and design their experiments. The sharing and discussion of beginning questions, claims and evidence were always done on the whiteboard in which either George or students were in charge. Although
students were responding when called upon, the researcher noticed that they rarely participated voluntarily. This was noticed during the first unit observations, which might be explained due to the existence of the researcher in the classroom and students unfamiliarity with the approach. In addition, being aware of the time constraint, George admitted that he needed to control the large group discussion with this year’s students to be able to get students moving forward. He had stated that, “they [students] kind of just sit there and stare at me. So I’ve kind of fallen back on a little more of a discussion of me asking the questions” (Int).

Unit preparation

George reflected his understanding of the concepts he wanted students to understand and the relationship among them. When he stated, “I have to understand the content myself to get there or help the kids get there” (Int). Although he taught the cell unit before following the SWH approach, he implemented a new SWH activity that would promote higher student cognitive actions and maintain robust understanding. The choice of activities was appropriate for promoting the big ideas and for the level of the students.

In summary, George’s implementation reflected confidence with the SWH and a student-oriented teaching approach. He was aware of his role as a facilitator and using questioning to promote student learning. His epistemological belief was compatible to his pedagogical practice. In his response to the interview, he revealed some of his goals of teaching science to his students, such as science literacy and understanding the nature of science. Further, he noticed that he had to initiate the discussion in large group discussion and be on the stage with this year students. George’s scores from the three ranking scales are illustrated in Table 15.
Table 15. George ranking sores

<table>
<thead>
<tr>
<th>Ranking scale</th>
<th>Dialogical scale</th>
<th>Controlling scale</th>
<th>Preparation scale</th>
<th>Composite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Score</td>
<td>6/10</td>
<td>3/5</td>
<td>3/5</td>
<td>12/20</td>
</tr>
</tbody>
</table>

*Roger.*

As stated earlier, the SWH was not a new teaching approach for Roger. Therefore, he was confident in his implementation, yet was not feeling confident with being observed. His lack of confident was reflected by his awareness of the researcher's presence in his classroom and his anxiousness to promote a dialogue interaction. Five on-site observations were conducted from the two units: ecosystem and cell. He provided a videotape of his SWH during the cell unit. Roger did not respond to the questionnaire items, and the researcher did not interview him for the same reason as George, the other science teacher from his school. His responses to the other researcher's interview questions about the SWH implementation were used in this study. Roger's observations revealed his struggle with classroom management. When giving time for small group discussion, a few groups were off task and he did basically nothing to bring them back on task. However, these students were able to provide answers when called upon when involved in large group discussions. Based on observing two SWH sessions, the independent rater scored Roger's implementation as 5 points on the 10-point scale providing the following reasons:

"Roger was almost anxious to answer student questions or inject the correct idea if students didn't come up with it quickly. The lack of students working in groups was a bit puzzling as well. He was also hesitant to put up anything, but what he thought were correct ideas on the board. The plus in the sessions was the way he tried to help students connect ideas to a previous unit on
ecosystems. Roger worked hard on those connections and why they related to the big ideas”.

**Dialogical interaction**

Roger’s implementation reflected his understanding of the role of questioning in promoting student learning. There was evidence of dialogical interaction in his classrooms. He was aware of his interaction skills—how to respond to students’ questions and how to respond to students’ answers. To guide his students through the process of sharing claims and evidence he used questioning and modeling to emphasize the desired type of student-student interaction by engaging his students in a discussion of the question: “what makes evidence convincing?” (Obs) He used open-ended questions and always required more from students when they responded. He rarely used judgmental phrases as a follow up to students’ responses. Sometimes he used “okay” in an extended tone to encourage the student to talk more. Also, he asked other students to reflect on their classmate’s response without rephrasing the response. The sharing of claims and evidence was always the students’ responsibility and accomplished as small group presentations. Each group presented their beginning question, testing procedures, observations, and claim and evidence. Other students asked questions and reflected on the presented knowledge. Students reflected understanding of the role of providing robust convincing evidence in making a generalization out of a claim. They provided suggestions like repeating the testing and trying to control more variables.

**Controlling of knowledge**

Students were comfortable in articulating their thinking and sharing their ideas. Roger was aware of his role of a discussion mediator. Similarly as George, the SWH activities were open inquiries that allowed students to ask their questions and design their investigation
procedures. Students were always in control of the discussion and sharing of claims and evidence on the whiteboard. Roger still displayed some hesitation in not telling the students what he wanted them to learn.

**Unit preparation**

As stated earlier, Roger and George worked collaboratively in preparing for the two implemented units. They tried to include different types of activities to promote different cognitive actions, such as observing, finding similarities and differences, and inductive thinking. Roger's first goal for his students was critical thinking which he stressed as, "it's learning how to investigate. Becoming a thinker" (Int). He tried to build upon students' prior knowledge and to facilitate the connection between the ecosystem unit and the cell unit.

Overall, Roger was able to implement dialogical interaction among students in his classroom; however, he was unable to motivate small group interaction. Roger had problems with his classroom management. Some students were having problems listening to their peers, sitting quietly, and/or being involved in small group discussion. The researcher was informed later that most of the students within this particular period had individual educational programs (IEPs). Although students benefit from expressing their ideas and reflecting on others ideas, such interaction must be monitored to maintain an effective learning environment for all students. Roger's scores from the three ranking scales are illustrated in Table 16.

<table>
<thead>
<tr>
<th>Ranking scale</th>
<th>Interaction scale</th>
<th>Controlling scale</th>
<th>Preparation scale</th>
<th>Composite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Score</td>
<td>5/10</td>
<td>2/5</td>
<td>3/5</td>
<td>10/20</td>
</tr>
</tbody>
</table>
Nick.

Nick’s attitude reflected his willingness to participate in the study and eagerness to learn more about the SWH. He did not feel intimidated when asking for help with the unit preparation. Nick taught the solution unit for the first time and chose to do it with the SWH. The researcher observed a videotape of Nick’s third SWH from the first unit and on-site observed 15 minutes of a period during an SWH within the second unit, classification. The independent rater gave Nick 4 points on the 10-point scale for the following reasoning:

“Lesson activity was very teacher directed, and student questions and input on how to test student ideas was not evident. Later I found out this was Nick’s first try at teaching this unit which probably explains his teacher-centered approach. Implication was there is one way to do this!”

Dialogical interaction

The activity observed was about Chromatography. Students were engaged and on task. There was evidence of student-student interaction, but the discussions were teacher directed. Students answered when called upon; Nick used “good” or “good question” (Obs) to respond to students’ beginning questions. Nick stated, “in the SWH approach, I feel more like a debate moderator where I am constantly asking questions and then follow-up questions, and more questions. I am allowing everyone to state their opinion” (Que).

Controlling of knowledge

Although Nick thought of himself as a “facilitator” (Que), his SWH included evidence of the opposite. Nick controlled students’ discussion in large group and used structured procedures. Further, he told them, “put your observation in a table” (Obs) and later he drew a table on the whiteboard for the students to make sure they all had the same
table. Instead of discussing the different variables within the activity, he directly pointed to the length of the color distance as an important variable. However, he stated that teachers "never have control over whether the students are learning. This approach gives the student more ownership in their learning" (Que). Unfortunately the sharing of claims and evidence happened in a different period, which the researcher was unable to observe.

**Unit preparation**

Nick understood the meaning of teaching for big ideas:

"I think that with the SWH it really forces [science teachers] to think about what it is that you really want the kids to know, what are your big ideas and is this particular activity going to help you reach that goal. It really forces you to be a little bit more selective in terms of activities that are going to be more open ended and allow for kids to really reach- number one- and number two is it really directly related to what your wanting to get out of that particular topic" (Int).

The observed activity was structured in that he provided the procedure yet invited students to ask their own questions.

In general, Nick was able to create a learning environment within his implementation of the SWH. Students were on task and answering teacher questions. Implementation reflected his struggle to play the role of a facilitator and promote more dialogical interaction in his classroom. He accepted the feedback and considered any suggestion as a path for improvement. Nick's scores from the three ranking scales are illustrated in Table 17.
Table 17. Nick ranking sores

<table>
<thead>
<tr>
<th>Ranking scale</th>
<th>Interaction scale</th>
<th>Controlling scale</th>
<th>Preparation scale</th>
<th>Composite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Score</td>
<td>5/10</td>
<td>2/5</td>
<td>3/5</td>
<td>10/20</td>
</tr>
</tbody>
</table>

**Sondra.**

The researcher observed videotapes of two SWHs from Sondra's first unit: the diffusion activity and the dialysis tubing activity. As stated before, although Sondra was familiar with the SWH, her implementation had never been observed nor was feedback provided to her before. Sondra responded to the questionnaire items, but was not interviewed. Her on-site observer, the science consultant at Area of Educational Agency 11, observed her twice and gave her 8 points on the 10-point scale providing the following reasons:

"Sondra's implementation has reached the "comfort" level for her, but not necessarily for her students. She values the information she receives from it too much. Because she is the only science teacher these students have had who requires a writing component in science, they are still novices. The only real problem I see is that the student inquiries she designs are very teacher directed".

The independent rater, based on his observations of Sondra's videotapes, scored her 4-5 on the 10 point scale, supporting his score with the following:

"Sondra directed the way to do investigation rather than setting out materials and saying "How would you show"? Students were on task and teacher expectations and classroom discipline were apparent. Teacher asks for claims based on observations. Students became more engaged when their ideas on
observations was asked for. Quite well done, except for a little too much
teacher direction in activity (lab) set up”.

**Dialogical interaction**

The two activities observed were teacher structured. While her questions were open-ended, there was not much dialogical interaction among students in her classroom. The interactions were teacher controlled, which matched her belief when stating that, “it [the SWH] requires constant questioning... It is 100% on-task work by the teacher” (Que). However, she promoted student sharing of observations and claims and evidence in small and large groups. She initiated discussion with students in small groups. “Okay” was the only phrase Sondra always used to respond to her students’ responses.

**Controlling of knowledge**

Sondra reflected good classroom management. She explained the SWH template and told her students what she was looking for in each component of the student template. She also assigned the reading segments from the chapter to help them support their claims. Her students were shy to interact with each other, which could be due to the taping. The structured activities reflected an opposite position of what she stated, “instead of “telling” the students how to do a lab, I have to carefully plan my questions to get them started on the lab” (Que). She further stated that, “I also have to be very flexible throughout the activity to allow the students to take a variety of directions with their ideas and experiments” (Que). In describing her role, Sondra used the metaphor “interpretive dance instructor” and explained it stating that, “I still have some control (i.e. I have given them the piece of music to work with) but they may use many dance steps to perform to it” (Que).
**Unit preparation**

Sondra was able to limit her units to a few big ideas that reflected her understanding of the content knowledge. She had implemented six SWH activities within her first unit and two activities within the second unit. As stated before, Sondra’s participation in the SWH was part of her research for her master’s degree. For the unit preparation Sondra claimed that, “I can generally use any activity with the SWH. Sometimes I have to change how I present the activity from the textbook or outside source so it is more student-centered and less teacher directed” (Que).

In general, Sondra’s implementation reflected her understanding of her discipline content knowledge. Her questions were either short answers or open-ended. Although there was evidence of small group discussion in her classroom, Sondra controlled the large group discussion. Sondra had good classroom management; however, her controlling of the discussion could be influenced by her controlling behavior. Sondra’s scores from the three ranking scales are illustrated in Table 18.

Table 18. Sondra ranking scores

<table>
<thead>
<tr>
<th>Ranking scale</th>
<th>Interaction scale</th>
<th>Controlling scale</th>
<th>Preparation scale</th>
<th>Composite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Score</td>
<td>5/10</td>
<td>2/5</td>
<td>3/5</td>
<td>10/20</td>
</tr>
</tbody>
</table>

**James.**

The researcher was able to remote-site observe four periods of James’ implementation. In addition, two of the observations were also videotapes. He had a strong respectful relationship with his students. He had invited the science consultant from Area Educational Agency 13 to observe his classrooms many times. Further, he was the first to
begin implementing the SWH unit in his school. He did not feel threatened by being observed and accepted all suggestions. James had responded to the questionnaire items, but did not agree to be interviewed. His on-site observer gave him 6 points on the 10 point scale for the following reasons: “[James] builds on [students] prior knowledge, coaches kids well with questions, encourages writing, challenges their thinking, [there is] great energy in the classroom, really encourages kids to talk to each other, very self-reflective”. Based on observing videotapes of two SWH periods for James, the independent rater gave him 5 points on the 10-point scale providing the following reasons:

“James started out with some good things. Group work was good, had a good discussion of how groups should work and why they were important. Large group questioning and discussion was problematical when James digressed to thumbs up thumbs down (yes/ no) kinds of responses. The direction of the discussion was not as well focused and getting student questions was later really what James was questioning. He could have listed student questions on the board and then have gotten to what he needed through their questions. He seemed to bounce between ideas on friction and gravity, and the students seemed to get lost, on what the big ideas were”.

**Dialogical interaction**

James reflected his struggle to always ask open-end questions, but his students did not seem bothered by him rephrasing the question. There was evidence of student-student interaction in small groups with James asking questions of students to direct their thinking. He was aware of the need to not provide judgmental phrases to promote more student interaction. James felt that he had improved in his questioning skills, because he used them more with the SWH approach.
**Controlling of knowledge**

As stated above, James had encouraged student-student small group discussion. He was willing to provide more time for discussion when needed. Students felt comfortable sharing and reflecting on each other’s ideas during large group discussion. Students’ beginning ideas were shared on the whiteboard. The activities were open-inquires with students generating their inquiries and investigation procedures. James described his role within the SWH using the following “of traffic cop at an athletic event”; he further explained, “I have a number of cars wanting to go different ways and I need to help them get to the same destination safely” (Que).

**Unit preparation**

James was able to limit the unit to one big idea and build on students’ prior knowledge; he invited them to investigate their beginning questions through open-inquiry. He knew that his role was “more of a facilitator of learning than a lecturer” (Que). James’s answer to the unit preparation item reflected his understanding of the constructivist teaching approach, “there is not as much pre-unit prep, but rather daily preparations in response to the students’ questions” (Que).

In summary, James had implemented some student-student dialogical interaction in small group and large group. He was building upon students’ prior knowledge and promoting learning through using open-inquiry labs. James was aware that he needed to work on his questioning skills. James’s scores from the three ranking scales are illustrated in Table 19.

<table>
<thead>
<tr>
<th>Ranking scale</th>
<th>Interaction scale</th>
<th>Controlling scale</th>
<th>Preparation scale</th>
<th>Composite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Score</td>
<td>5/10</td>
<td>3/5</td>
<td>2/5</td>
<td>10/20</td>
</tr>
</tbody>
</table>
Summary

Teachers in this level did not fully reflect a student-oriented approach. Most of the teachers’ activities recommended by the SWH teacher template were implemented. Teachers asked more open questions of the students and the classroom interactions were more dialogical, yet teachers still struggled to implement open inquiry.

Level III Implementation

The only two teachers in this level of implementation were Lucy from the Anita public school district and John from the Boone public school district. Table 20 includes a summary of the type and number of observations conducted for each teacher in this level.

Table 20. Observational types for Level III teachers

<table>
<thead>
<tr>
<th>Teacher</th>
<th>District</th>
<th>Observer</th>
<th>Type</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lucy</td>
<td>Anita public school</td>
<td>The researcher</td>
<td>Videotape</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Retired teacher</td>
<td>Videotape</td>
<td>2</td>
</tr>
<tr>
<td>John</td>
<td>Boone public school</td>
<td>The researcher</td>
<td>On-site</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Graduate student</td>
<td>On-site</td>
<td>3+</td>
</tr>
</tbody>
</table>

* Indicates more than three times observation

Lucy.

The researcher was not able to remote-site observe Lucy due to the firewall protection created in her school during the summer of 2003. Fortunately, the researcher was able to observe two SWHs from Lucy’s last unit, work and machines, which was implemented as part of teaching physical science. Lucy had been using the SWH for three years. She was able to integrate the language arts, reading, writing, and (sometimes) math in her teaching of the science unit while using the SWH. Lucy was very cooperative with research staff and eager to be observed. She responded to the questionnaire items and agreed to be interviewed.
Her on-site observer, the science consultant from Area Educational Agency 13, was able to observe Lucy twice and scored her implementation as 8 points on the 10-point ranking scale for the following reasoning: “Lucy builds on [students'] prior knowledge, coaches kids well with questions, encourages writing, great energy in the classroom, challenges their thinking, very kid directed, uses awesome reading and writing strategies, high expectations for kids, full participation of class”.

The independent rater, based on observation of the videotape, scored Lucy as 7-8 on the 10-point scale providing the following reasons:

“Good questioning skills. Could still ask for more student to student discourse, but asks probing questions and makes students explain in depth what they think/understand. She uses visual cues to enhance understanding. High level questions from students. Good implementation of SWH. Students operate in disciplined atmosphere, but for grade level they are expected to work on their own and come up with their own ideas. There is little evidence that the teacher is providing answers therefore students are on task trying to find their own evidence to support claims and answer their questions”.

**Dialogical interaction**

Lucy’s implementation of the SWH reflected her confidence with the approach and the role required from her, as she stated, “*my questioning becomes richer as I help the students answer their questions themselves*” (Que). She promoted student-student interaction in small and large group; required more from student responses by asking them how and why questions; wisely used the judgmental phrases, such as “*good question*” or “*okay*” (Obs), and
did not answer student questions. Students were on task with the teacher moving around and interacting with each group by asking questions.

**Controlling of knowledge**

Different beginning questions were put on the whiteboard. Students in groups were to choose their beginning question and testing procedure. Each activity was related to the big idea. Students were comfortable discussing their ideas. Lucy described her role as "the conductor of the symphony- i.e. my classroom. I look for ways to help them solve the problem they are trying to solve on their own" (Que).

**Unit preparation**

Lucy was aware that the difference in her unit preparation was centered on choosing the big ideas. As she explained, "my big ideas drive the teaching. I look for activities that I know will expand upon the big ideas and that I can modify so that the students can investigate and explore" (Que). She further explained the process of her unit preparation stating that,

"the first thing I do is I go to my standards and benchmarks. I decide what unit I am going to teach based on my standards and benchmarks then I make my big ideas based on that. Then I take that and I go look for materials weather it's in my textbook, a FOSS kit, or information from the Internet" (Int).

Observation of her SWH includes evidence of connecting activities to big ideas.

In general, Lucy was able to implement the SWH in a way that reflected a student-oriented approach. She adapted the SWH to fit her students' level. Activities implemented
were open-inquiry that allowed students to ask and design their own procedure. Lucy's scores from the three ranking scales are illustrated in Table 21.

Table 21. Lucy ranking scores

<table>
<thead>
<tr>
<th>Ranking scale</th>
<th>Interaction scale</th>
<th>Controlling scale</th>
<th>Preparation scale</th>
<th>Composite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Score</td>
<td>8/10</td>
<td>4/5</td>
<td>4/5</td>
<td>16/20</td>
</tr>
</tbody>
</table>

*John.*

The researcher was able to observe John on-site during his fourth unit, genetics. The activity was about ethical issues related to genetic disorders. Students were debating for or against the case presented. John was very cooperative with research staff and eager to be observed and apply suggestions. He responded to the questionnaire items and agreed to be interviewed. His on-site observer observed him many times and scored his implementation as 8-9 points on the 10-point ranking scale for the following reasoning:

"John allows for student interaction. Have a good questioning skill. Students are always on task in his class. He listens to feedback suggestions and applies them. In the beginning, he struggled with the unit preparation. He developed rich understanding of student-oriented approach inconsistent with his role".

The independent rater, based on observation of John's classroom, scored him as 8 points on the 10-point scale providing these reasons: "John has promoted dialogical discussion among students in small and large group. He has a good questioning skill, does not provide information to student, answers their questions with a question, and has a good class management."
**Dialogical interaction**

The activity observed was a debate about hiring a person with Huntington's disease. Students were divided to two groups: for and against. All students were on task and engaged in the activity, discussing issues to provide supporting for their stand on the issue. The teacher instructed them to consider what the other team might think of as well and think of how to weaken their points. John adopted the role of a debate mediator and invited students from each team to share, respond, and reflect on each other. John was aware of who had talked and who did not and tried to invite all students to share. John's goal for himself was "to become better all the time at questioning and focusing on what is really important for students to get out of the course" (Que).

**Controlling of knowledge**

Students wrote their reasoning on the whiteboard. John did not take a position, thus allowing student to decide for themselves. John nicely stated his opinion regarding controlling student learning, stating that, "I feel that I still have control in as far as the big ideas that are chosen but that the students are doing more themselves to learn rather than need on me to supply them with information" (Que).

**Unit preparation**

The genetic unit was John's fourth unit using the SWH. His choice of big ideas and SWH activities reflected his understanding of the content knowledge in relation to the instructional approach. He chose different activities that allowed for student interaction which promoted learning. His conceptual questions were seeking student understanding of the knowledge learned in their life.
In general, John’s implementation reflected his understanding of the SWH and the role required of him. He was aware of the role of his questioning to promote discussion. Students were interacting with each other and on task. John had good classroom management. His role was not to give information to student; rather his role was to help them construct their knowledge through interacting with each other and engaging in the activity. John’s scores from the three ranking scales are illustrated in Table 22.

Table 22. John ranking scores

<table>
<thead>
<tr>
<th>Ranking scale</th>
<th>Interaction scale</th>
<th>Controlling scale</th>
<th>Preparation scale</th>
<th>Composite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Score</td>
<td>8/10</td>
<td>4/5</td>
<td>4/5</td>
<td>16/20</td>
</tr>
</tbody>
</table>

Summary

Teachers in this level reflected confidence in implementing student-oriented approach. The implementation of the teacher’s activities, recommended by the SWH teacher template, became essential in teacher practice. Teachers asked open ended questions of the students; the classroom interactions were more dialogical, and students had many opportunities to be involved in argument and construct their knowledge. The teachers’ understanding of the role of dialogue in meaning making was reflected from their questions. The unit preparation conveyed seeing the bigger picture of classroom activity.

Quantitative Results

The goal of the statistical analysis was to answer the third research question—what is the effect of teachers’ levels of implementations of the SWH on students’ learning of science concepts? Analyses of student outcomes from the total conceptual scores on the unit test were reported for a few teacher case studies that satisfied the conditions of applicable
statistical analysis. That is, the researcher was able to control as many variables that might contribute to the explanation of the tested hypothesis. Among the variables considered were the use of the same instrument (conceptual questions) to measure student outcomes, the implementation of the same unit within the same grade level, and the use of the same SWH activities to promote the learning of the same big ideas. Only when these variables were controlled for, was the researcher able to statistically analyze student outcomes. The researcher was aware of other variables that might influence student outcomes yet were difficult to be controlled for in educational research.

This section will be organized according the quantitative research design in which statistical analysis from selective teachers case study following the untreated control group design will be reported first, followed by two sets of statistical analysis between teachers from the one-group pretest-posttest design.

**Untreated Control Group Design**

Two case studies of teachers from Level I implementation were presented. As explained in the method chapter, out of the 18 teachers involved five teachers followed this design. These teachers were James, Danny, Janette, and Rachel from Riverside public school district, and Brad from Central junior/high district. Unfortunately, only Rachel’s and Brad’s student scores were analyzed. Janette although analyzed was not reported; hence, the researcher did not observe her and cannot provide any conclusions. James did not provide the researcher with his student scores. Although Danny provided the researcher with his student scores, he was excluded from the statistical analysis because he used yes/no rubric to score his student conceptual questions due to the time consuming nature of the marking process.
**Brad case study**

Brad was ranked as Level I teacher. A descriptive summary of his student scores is presented in Table 23. Internal consistency coefficient (.22) was obtained from student posttest scores on three conceptual questions (N= 40). Analysis of variance was conducted to investigate the difference among students in groups in the pretest conceptual question scores and in the baseline test scores. ANOVA results show non-significant difference in pretest conceptual question scores for group (MC = 41.52, SE = 2.0; MT = 47.09, SE = 1.9). Similar results were obtained for the baseline scores (MC = 51.84, SE = 4.7; MT = 61.43, SE = 4.5).

Table 23. Descriptive summary for Brad case study scores

<table>
<thead>
<tr>
<th>Group</th>
<th>Baseline score</th>
<th>Pretest CQs</th>
<th>Posttest CQs</th>
<th>Improvement score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>51.84</td>
<td>41.52</td>
<td>83.63</td>
</tr>
<tr>
<td></td>
<td>St Dev</td>
<td>18.27</td>
<td>8.15</td>
<td>16.30</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>9</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Control</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>61.43</td>
<td>47.09</td>
<td>78.84</td>
</tr>
<tr>
<td></td>
<td>St Dev</td>
<td>22.54</td>
<td>9.23</td>
<td>12.12</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>12</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>9</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Treatment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

After the unit implementation, analysis of covariance was conducted to investigate differences in posttest conceptual question score among students in groups after controlling for pretest conceptual questions. The results indicated non-significant difference among group in the posttest conceptual question score (MC = 85.51, SE = 3.1; MT = 77.13, SE = 3.0). However, the covariate of pretest conceptual questions was significantly related to the dependent variable of posttest conceptual questions (F(1,37)=6.855, p<.013, partial η²=.156). The results of an ANCOVA, conducted to investigate differences in student conceptual question improvement scores among groups after controlling for baseline test,
showed a significant difference ($F(1,37)=5.652, p<.023$, partial $\eta^2=.133$) where the control group ($M_C = 0.75, SE = 0.05$) outperformed the treatment group ($M_T = 0.58, SE = 0.05$). Further, the covariate of baseline test was significantly related to the dependent variable of improvement score ($F(1,37)=7.041, p<.012$, partial $\eta^2=.160$).

A 2 x 2 analysis of covariance was conducted to determine the effect of group and gender on student posttest conceptual questions, when controlling for pretest conceptual question scores. The main effects of both gender ($M_m = 79.56, SE = 2.9; M_f = 83.58, SE = 3.2$) and group ($M_C = 85.43, SE = 3.2; M_T = 77.71, SE = 3.0$) were not significant as was the interaction between gender and group. However, the covariate of pretest significantly related to the dependent variable of posttest conceptual question score ($F(1,35)=5.666, p<.023$, partial $\eta^2=.139$).

A 2 x 2 x 3 analysis of covariance was conducted to determine the effect of group, gender, and student's achievement levels on posttest conceptual question scores when controlling for pretest conceptual question scores (achievement level was determined based on the baseline scores as described in the method chapter). While the main effect for group was significant ($F(1,18)=4.64, p<.045$, partial $\eta^2=.205$) where the control group ($M_C = 91.78, SE = 5.6$) outperformed the treatment group ($M_T = 73.19, SE = 4.8$), all other main effect results for ability ($M_L = 76.04, SE = 5.56; M_M = 75.45, SE = 6.26; M_H = 92.02, SE = 6.0$) and gender ($M_m = 80.23, SE = 4.13; M_f = 83.33, SE = 5.41$) were not significant. Further, the two-way and the three-way interaction effect results were not significant. Table 24 included descriptive results of student posttest conceptual questions scores generated based on the baseline scores.
Table 24. Summary of Brad posttest score

<table>
<thead>
<tr>
<th>Group</th>
<th>Ability</th>
<th>Gender</th>
<th>Mean</th>
<th>Std Dev</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>Low</td>
<td>Male</td>
<td>72.22</td>
<td>27.96</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Female</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Male</td>
<td>88.88</td>
<td>.00</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Female</td>
<td>83.33</td>
<td>14.34</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>Male</td>
<td>100.00</td>
<td>.</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Female</td>
<td>100.00</td>
<td>.</td>
<td>1</td>
</tr>
<tr>
<td>Treatment</td>
<td>Low</td>
<td>Male</td>
<td>70.37</td>
<td>6.42</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Female</td>
<td>77.78</td>
<td>15.71</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Male</td>
<td>70.37</td>
<td>6.42</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Female</td>
<td>77.78</td>
<td>.</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>Male</td>
<td>80.00</td>
<td>12.17</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Female</td>
<td>86.11</td>
<td>16.67</td>
<td>4</td>
</tr>
</tbody>
</table>

The overall results supported the findings of the qualitative data—that is, a Level I teacher struggled to promote authenticated inquiry learning environment to promote learning of scientific concepts. In fact, students in the control group performed better than students in the treatment group. The main effects of gender and achievement ability were conducted on a small sample size for each combination cell; the researcher, at this point, did not consider the results of these two independent variables. Larger sample size per each cell is needed.

**Rachel case study**

Rachel was also a Level I teacher. A descriptive summary of her student scores is presented in Table 25. Internal consistency coefficient (0.76) was obtained from student posttest scores on three conceptual questions \((N = 54)\). Analysis of variance was conducted to investigate the difference among students in groups in the pretest conceptual question scores and in the baseline test scores. The results showed non-significant differences among students in groups for both pretest conceptual question scores \((M_C = 0.88, SE = 0.63; M_T = 0.46, SE = 0.46)\) and baseline test scores \((M_C = 55.26, SE = 4.39; M_T = 58.33, SE = 3.19)\).
Table 25. Descriptive summary for Rachel case study scores

<table>
<thead>
<tr>
<th>Group</th>
<th>Baseline score</th>
<th>Pretest CQs</th>
<th>Posttest CQs</th>
<th>Improvement score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>55.26</td>
<td>39.25</td>
<td>30.08</td>
</tr>
<tr>
<td></td>
<td>StDev</td>
<td>17.52</td>
<td>28.64</td>
<td>28.37</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>M</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>F</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Control</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatment</td>
<td>Mean</td>
<td>58.57</td>
<td>47.86</td>
<td>47.71</td>
</tr>
<tr>
<td></td>
<td>StDev</td>
<td>20.13</td>
<td>30.81</td>
<td>30.73</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>M</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td></td>
<td>F</td>
<td>19</td>
<td>19</td>
</tr>
</tbody>
</table>

After the unit implementation, analysis of covariance was conducted to investigate the differences in posttest conceptual question scores among students in groups when controlling for pretest conceptual questions. The results showed that the difference between groups was not significant, ($M_C = 38.47, SE = 6.83; M_T = 46.94, SE = 4.96$). Further, the covariate of pretest conceptual questions was not significantly related to the dependent variable of posttest conceptual questions.

The results of the ANCOVA, conducted to investigate differences in student conceptual question improvement scores among groups after controlling for baseline test, indicated that groups did not differ significantly ($M_C = 40.47, SE = 6.34; M_T = 45.65, SE = 4.60$). Further, the covariate of baseline test was not significantly related to the dependent variable of improvement score.

A 2 x 2 analysis of covariance was conducted to determine the effect of group and gender on student posttest conceptual question scores, controlling for pretest conceptual question scores. The results showed that the main effect for group did not differ significantly, ($M_C = 38.01, SE = 6.32; M_T = 47.20 SE = 4.66$). However, the main effect for gender was significant ($F(1,49)=6.813, p<.012, \eta^2=.122$) where females ($M_f = 52.98, SE = 5.39$)
outperformed males ($M_m = 32.22, SE = 5.77$). The interaction between gender and group was not significant. However, the covariate of pretest was significantly related to the dependent variable of posttest conceptual question score ($F(1,49)=5.226, p<.027, \text{partial } \eta^2=.096$).

A 2 x 2 x 3 analysis of covariance to determine the effects of group, gender, and student achievement level on posttest conceptual question scores while controlling for pretest conceptual question score was conducted. While the main effect for student achievement level was significant ($F(2,24)=3.654, p<.041, \text{partial } \eta^2=.233$) where students in middle achievement levels ($M_M = 50.31, SE = 7.72$) and high achievement levels ($M_H = 55.34, SE = 14.91$) achievement levels outperformed students in low achievement level ($M_L = 13.61, SE = 12.22$), all other main effect results for group ($M_C = 37.74, SE = 10.51; M_T = 41.77, SE = 7.12$) and gender ($M_m = 32.17, SE = 10.64; M_f = 47.33, SE = 8.18$) were not significant. Further, the two-way and the three-way interaction effect results were also not significant.

The covariate of pretest score was not significantly related to the dependent variable of posttest conceptual questions. Table 26 includes descriptive results of student posttest conceptual questions scores generated based on the baseline scores.

The overall results were consistent with the findings of the qualitative data—that is, a Level I teacher failed to promote a significant learning environment to promote student understanding of scientific concepts. The main effect that was significant for gender in 2 x 2 ANCOVA analyses disappeared in 2 x 2 x 3 ANCOVA analysis. The main effect of gender and student achievement level was conducted on a small sample size for each combination cell; the researcher did not at this point considered the results of these two independent variables, because a larger sample size per each cell was required for meaningful comparison to be made.
One-Group Pretest-Posttest Design

Four teachers’ case studies were statically analyzed with teacher as the independent variable instead of group: the two teachers from Ames public school district, George and Roger, who were ranked in Level III implementation and the two teachers from Boone public school district, Gary and John, who were ranked in Level I and Level III implementations.

**George and Roger case studies**

The researcher analyzed the scores of 141 students after excluding students in individual educational program and the missing data from baseline test score, pre- and posttest scores. Internal consistency coefficient (0.74) was obtained from student posttest scores on two conceptual questions (\( N = 141 \)). The results were based on the analysis of the cell unit. A descriptive summary of student scores is presented in Table 27. Before the unit implementation, analysis of variance was conducted to investigate the difference in the baseline test scores among students of similar teacher rank. The result showed a non-significant difference among students (\( M_R = 65.17, SE = 1.95; M_G = 66.28, SE = 1.65 \)).
Table 27. Descriptive summary for George and Roger case study cell unit scores

<table>
<thead>
<tr>
<th>Group</th>
<th>Baseline Test</th>
<th>Pretest CQs</th>
<th>Posttest CQs</th>
<th>Improvement Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>George</td>
<td>Mean</td>
<td>66.28</td>
<td>10.14</td>
<td>61.59</td>
</tr>
<tr>
<td></td>
<td>St Dev</td>
<td>13.65</td>
<td>8.60</td>
<td>27.32</td>
</tr>
<tr>
<td>N</td>
<td>M</td>
<td>39</td>
<td>39</td>
<td>39</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>43</td>
<td>43</td>
<td>43</td>
</tr>
<tr>
<td>Roger</td>
<td>Mean</td>
<td>65.17</td>
<td>40.36</td>
<td>77.22</td>
</tr>
<tr>
<td></td>
<td>St Dev</td>
<td>16.63</td>
<td>15.50</td>
<td>16.69</td>
</tr>
<tr>
<td>N</td>
<td>M</td>
<td>30</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>29</td>
<td>29</td>
<td>29</td>
</tr>
</tbody>
</table>

After the unit implementation, analysis of covariance was conducted to investigate the differences in posttest conceptual question scores among students of similar teacher rank after controlling for pretest conceptual question scores. The results showed a non-significant difference ($M_R = 65.27, SE = 3.98; M_G = 70.19, SE = 3.14$) in posttest conceptual questions for students of similar teacher rank; however, the covariate of pretest conceptual questions was significantly related to the dependent variable of posttest conceptual question score ($F(1,138)=18.865, p<.000, \eta^2=.120$).

Analysis of covariance was conducted to investigate the impact of similar teacher rank on student conceptual questions improvement scores after controlling for baseline test score. The results showed that students did not differ significantly in their conceptual questions improvement scores ($M_R = 61.98, SE = 3.34; M_G = 59.88, SE = 2.87$). However, the covariate of baseline test was significantly related to the dependent variable of improvement score ($F(1,138)=22.29, p<.000, \eta^2=.139$).

A 2 x 2 analysis of covariance was conducted to determine the effect of similar teacher rank and gender on student improvement score when controlling for baseline score. The results showed a significant main effect for gender ($F(1,135)=3.899, p<.050, \eta^2=.136$).
in which female students ($M_f = 64.26$, $SE = 3.14$) outperformed male students ($M_m = 55.39$, $SE = 3.14$); however, the main effect for teacher rank was not significant ($M_R = 61.85$, $SE = 3.36$; $M_Q = 57.80$, $SE = 2.83$). Further, the two-way interaction effect between gender and teacher was not significant. The covariate of baseline was significantly related to the dependent variable of conceptual question improvement score ($F(1,135)=26.096$, $p<.000$, partial $\eta^2=.162$).

A 2 x 2 x 3 analysis of covariance to determine the effect of teacher rank, gender, and student achievement level on student conceptual question improvement score when controlling for baseline score was conducted. While the main effects for teacher rank ($M_R = 62.15$, $SE = 1.76$; $M_G = 59.31$, $SE = 1.34$) and gender ($M_m = 60.84$, $SE = 1.42$; $M_f = 60.62$, $SE = 1.76$) were not significant, the main effect for student achievement level was significant ($F(2,87)=368.78$, $p<.000$, partial $\eta^2=.894$) with high achievement students ($M_H = 90.08$, $SE = 1.59$) outperformed middle achievement students ($M_M = 68.73$, $SE = 2.46$) and high and middle outperformed low achievement students ($M_L = 23.38$, $SE = 1.76$). Further, all two-way and three-way interaction effect results were not significant. Further, the covariate of baseline test was not significantly related to the dependent variable of conceptual question improvement score. Table 28 included descriptive summary of students’ improvement score for George and Roger.

In summary, students’ conceptual questions improvement scores were used to detect student difference instead of posttest conceptual questions scores to reduce any confounding factor that might resulted from teacher scoring. Although students differed in their pretest conceptual question scores before the study due to differences in covering the content in upper elementary level, the baseline test scores were not significantly different among
students. After the study, the improvement scores indicated that the same teacher rank impacted student learning almost in the same level. The significant main effect for gender in the 2 x 2 analysis of covariance (in favor of female) disappeared in the 2 x 2 x 3 analysis of covariance when controlling for baseline test. The main effect for teacher implementation level did not impacted student learning with respect to their achievement level. More sample size in each combination cell is needed to further investigate the main effect differences.

Table 28. Summary of George and Roger cell unit conceptual question improvement score

<table>
<thead>
<tr>
<th>Group</th>
<th>Ability</th>
<th>Gender</th>
<th>Mean</th>
<th>Std Dev</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>George</td>
<td>Low</td>
<td>Male</td>
<td>22.23</td>
<td>13.15</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Female</td>
<td>19.49</td>
<td>9.16</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Middle</td>
<td>Male</td>
<td>68.17</td>
<td>2.75</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Female</td>
<td>65.82</td>
<td>5.02</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>Male</td>
<td>89.43</td>
<td>8.02</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Female</td>
<td>90.52</td>
<td>8.23</td>
<td>14</td>
</tr>
<tr>
<td>Roger</td>
<td>Low</td>
<td>Male</td>
<td>27.05</td>
<td>11.85</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Female</td>
<td>22.38</td>
<td>11.99</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Middle</td>
<td>Male</td>
<td>69.24</td>
<td>2.42</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Female</td>
<td>68.80</td>
<td>1.92</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>Male</td>
<td>90.25</td>
<td>8.74</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Female</td>
<td>92.40</td>
<td>9.96</td>
<td>9</td>
</tr>
</tbody>
</table>

**Gary and John case studies**

As stated earlier, Gary and John implemented their first unit, ecology, collaboratively. That is, the same SWH activities were implemented to promote learning of the same big ideas. Further, they used the same pre- posttest instrument to measure student understanding of the unit concepts. This enabled the analysis of student conceptual scores among levels of teacher implementation. Internal consistency coefficient (0.86) was obtained from student posttest scores on four conceptual questions ($N = 163$). A descriptive summary of student
scores in baseline test, pretest conceptual questions, posttest conceptual question, and improvement scores is presented in Table 29.

Table 29. Descriptive summary for John and Gary case study cell unit scores

<table>
<thead>
<tr>
<th>Group</th>
<th>Baseline Test</th>
<th>Pretest CQs</th>
<th>Posttest CQs</th>
<th>Improvement Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>John</td>
<td>Mean</td>
<td>45.02</td>
<td>22.78</td>
<td>59.40</td>
</tr>
<tr>
<td></td>
<td>St Dev</td>
<td>15.07</td>
<td>11.67</td>
<td>17.53</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>38</td>
<td>38</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Gary</td>
<td>Mean</td>
<td>43.55</td>
<td>6.88</td>
<td>54.00</td>
</tr>
<tr>
<td></td>
<td>St Dev</td>
<td>14.14</td>
<td>7.35</td>
<td>15.65</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>42</td>
<td>42</td>
<td>42</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>34</td>
<td>34</td>
<td>34</td>
</tr>
</tbody>
</table>

Analysis of variance was conducted on student baseline scores to investigate the difference among students of each teacher prior to the SWH implementation. The results showed a non-significant difference ($M_J = 45.02$, $SE = 1.56$; $M_G = 43.55$, $SE = 1.68$) among students of the two teachers.

After the unit implementation, analysis of covariance was conducted to investigate the effect of teacher rank on student conceptual question improvement scores after controlling for baseline test scores. The result showed a non-significant difference ($M_J = 47.79$, $SE = 1.69$; $M_G = 51.31$, $SE = 1.82$); further, the covariate of baseline test scores was significantly related to the dependent variable of improvement scores ($F(1,161)=38.85$, $p<.000$, partial $\eta^2=.194$).

A 2 x 2 analysis of covariance was conducted to determine the effect of teacher rank and gender on student conceptual question improvement score when controlling for baseline score. The main effects of both teacher rank ($M_J = 47.32$, $SE = 1.7$; $M_G = 51.3$, $SE = 1.8$) and gender ($M_m = 47.57$, $SE = 1.78$; $M_f = 51.07$, $SE = 1.77$) were not significant nor was the two-
way interaction between gender and teacher; however, the covariate of baseline was significantly related to the dependent variable of improvement score ($F(1,159)=38.99$, $p<.000$, partial $\eta^2=.197$).

A 2 x 2 x 3 analysis of covariance to determine the effect of teacher rank, gender, and student achievement level on student conceptual question improvement scores was conducted. The results showed non-significant main effects of both teacher rank ($M_J = 45.93$, $SE = 2.29$; $M_G = 51.90$, $SE = 2.95$) and gender ($M_m = 46.58$, $SE = 2.71$; $M_f = 51.26$, $SE = 2.57$); however, the main effect for student achievement level was significant ($F(2,104)=11.72$, $p<.000$; partial $\eta^2=.184$) where high achievement students ($M_H = 61.14$, $SE = 3.25$) outperformed both middle achievement students ($M_M = 48.66$, $SE = 2.41$) and low achievement students ($M_L = 36.96$, $SE = 3.87$) and Middle achievement outperformed low achievement students. All two-way and three-way interaction effect results were not significant also. Table 30 included descriptive summary of John and Gary improvement score.

Table 30. Summary of John and Gary cell unit conceptual question improvement score

<table>
<thead>
<tr>
<th>Group</th>
<th>Ability</th>
<th>Gender</th>
<th>Mean</th>
<th>Std Dev</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
<td>Male</td>
<td>17.64</td>
<td>11.03</td>
<td>12</td>
</tr>
<tr>
<td>John</td>
<td></td>
<td>Female</td>
<td>20.61</td>
<td>7.84</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Male</td>
<td>46.84</td>
<td>4.03</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Female</td>
<td>46.79</td>
<td>4.32</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>Middle</td>
<td>Male</td>
<td>67.71</td>
<td>5.08</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Female</td>
<td>65.46</td>
<td>3.30</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>Male</td>
<td>18.05</td>
<td>6.64</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Female</td>
<td>19.88</td>
<td>5.69</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Male</td>
<td>43.77</td>
<td>3.61</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Female</td>
<td>43.07</td>
<td>4.16</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Middle</td>
<td>Male</td>
<td>62.09</td>
<td>3.87</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Female</td>
<td>61.40</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>Male</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Female</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
In summary, similarly to Roger and George, student conceptual questions improvement scores were used as to detect student difference instead of posttest conceptual questions scores to reduce any confounding factor that might result from teacher scoring.

Results obtained from the analysis of the conceptual questions improvement scores after the study indicated that teachers ranked in different levels had non-significant impact on student learning after controlling for baseline score, which did not replicate results obtained from the pilot study. The significant main effect for gender in the 2 x 2 and 2 x 2 x 3 analysis of covariance when controlling for baseline test was not significant, but the main effect for student achievement level was significant. A larger sample size in each combination cell is needed to further investigate the main effect differences in student achievement level and gender. Further, the overall quantitative results replicated the results obtained from the pilot study conducted during the 2002/2003 school academic year. That is, Level I teachers were not able to create authenticated inquiry-based learning environment to promote student learning.
CHAPTER SIX

Discussion

Overview

This chapter aims to address the changes associated with teacher implementation of the SWH as an inquiry-based approach. A primary goal of the study was to shed light on the question: what is (are) the main characteristic(s) that define different levels of the SWH implementation? The case study design adopted for this study allowed the researcher to gather rich information regarding each teacher's implementation of the SWH. Although a goal was to develop a set of criteria to define levels of implementation, the researcher would like to emphasize the point that each teacher's implementation of the SWH was different; therefore, the generated criteria did not necessarily indicate they should appear for each teacher within the designated level. Further, under the umbrella of professional development, criteria to define levels of implementation are not reflecting distinctive phenomenon; rather, they are indicating a continuum to reflect a process of developing professional practice.

The discussion within this chapter defines the shared features of teacher implementation within each level and across levels to assess characteristic(s) for defining levels of implementation within the SWH partnership project. The composite scores generated for the 16 teachers presented in Table 31 are arranged in descending order based on their composite scores. The difference within the composite scores occurred due to the differences observed during classroom practice. Further, the generated scores for all the teachers emphasized the point of continuity of the scaling mechanism used to distinguish the levels of implementation. While some teachers were ranked as Level I, they were actually in the transition phase located between the upper limit of the Level I and the lower limit of
Level II. Before proceeding, the researcher would like to point out that Janette and Mandy were excluded from this discussion for the lack of observational data.

The chapter, therefore, will be organized around two major questions. What are some essential characteristics that influence teacher implementation of the SWH? In addition, how are these characteristic interpreted from the constructivist teaching model (Simon, 1995) and the professional development model (Hand, 1996)?

Table 31. Participating teacher ranking scores

<table>
<thead>
<tr>
<th>Level</th>
<th>Teacher</th>
<th>Interaction</th>
<th>Controlling</th>
<th>Preparation</th>
<th>Composite</th>
</tr>
</thead>
<tbody>
<tr>
<td>III</td>
<td>John</td>
<td>8/10</td>
<td>4/5</td>
<td>4/5</td>
<td>16/20</td>
</tr>
<tr>
<td></td>
<td>Lucy</td>
<td>8/10</td>
<td>4/5</td>
<td>4/5</td>
<td>16/20</td>
</tr>
<tr>
<td>II</td>
<td>George</td>
<td>6/10</td>
<td>3/5</td>
<td>3/5</td>
<td>12/20</td>
</tr>
<tr>
<td></td>
<td>James</td>
<td>5/10</td>
<td>3/5</td>
<td>2/5</td>
<td>10/20</td>
</tr>
<tr>
<td></td>
<td>Sondra</td>
<td>5/10</td>
<td>2/5</td>
<td>3/5</td>
<td>10/20</td>
</tr>
<tr>
<td></td>
<td>Roger</td>
<td>5/10</td>
<td>2/5</td>
<td>3/5</td>
<td>10/20</td>
</tr>
<tr>
<td></td>
<td>Nick</td>
<td>5/10</td>
<td>2/5</td>
<td>3/5</td>
<td>10/20</td>
</tr>
<tr>
<td>I</td>
<td>Gary</td>
<td>4/10</td>
<td>2/5</td>
<td>3/5</td>
<td>9/20</td>
</tr>
<tr>
<td></td>
<td>Matt</td>
<td>4/10</td>
<td>2/5</td>
<td>2/5</td>
<td>8/20</td>
</tr>
<tr>
<td></td>
<td>Billy</td>
<td>4/10</td>
<td>2/5</td>
<td>2/5</td>
<td>8/20</td>
</tr>
<tr>
<td></td>
<td>Danny</td>
<td>4/10</td>
<td>2/5</td>
<td>1/5</td>
<td>7/20</td>
</tr>
<tr>
<td></td>
<td>Rose</td>
<td>3/10</td>
<td>1/5</td>
<td>2/5</td>
<td>6/20</td>
</tr>
<tr>
<td></td>
<td>Brad</td>
<td>3/10</td>
<td>1/5</td>
<td>1/5</td>
<td>5/20</td>
</tr>
<tr>
<td></td>
<td>Danielle</td>
<td>2/10</td>
<td>1/5</td>
<td>1/5</td>
<td>4/20</td>
</tr>
<tr>
<td></td>
<td>Rodney</td>
<td>1/10</td>
<td>1/5</td>
<td>1/5</td>
<td>3/20</td>
</tr>
<tr>
<td></td>
<td>Rachel</td>
<td>1/10</td>
<td>1/5</td>
<td>1/5</td>
<td>3/20</td>
</tr>
</tbody>
</table>

*Levels of Implementation Criteria*

Based on the different data collecting instruments, observations, questionnaires, and interviews, the researcher was able to define four essential characteristics that distinguished teacher levels of the SWH implementation.
Classroom Management

Evidence from several case studies of teachers in Level I implementation revealed that teachers in this level lacked understanding of classroom management, which affected their ability to separate classroom management from learning. This issue must be thoroughly addressed with teachers prior to any attempt to make changes within teaching practice to constructivist teaching approaches.

Rose, who admitted that being a "control freak" (Int) made her rush her students to finish each SWH activity in 35 minutes because she was afraid to lose control of classroom management, especially with students talking in small groups and moving around. Also, because of her obsession with managing materials needed for investigation, she refrained from allowing her students to ask their own questions, as she clearly stated "with that [students asking their questions] how would I know if I have the stuff that they're gonna want to ask the questions about?" (Int). Therefore, she deprived the students of ownership and posed the question herself to make sure she would have the materials needed. Similar to Rose was Rodney, who rushed two SWH activities in 60 minutes to maintain control of classroom management.

On the contrary, Brad and Danielle were other examples of opposite extremes of classroom management. Both teachers lost control in their classrooms due to the lack of understanding the differences between management and learning. Some students were not on tasks, socializing and/or disturbing their peers and the teachers basically did nothing to overcome such problems. The two opposite examples impeded the teacher's professional development. The lack of teacher understanding of classroom management impacted how learning occurred when using constructivist teaching approaches. In turn, teachers attributed
student failure to understanding the scientific knowledge to the new teaching approach (Windschitl, 2002) rather than blaming it on their own bad implementation.

**Dialogical Interaction**

As stated earlier, science teaching practice should be shifted from the traditional didactic approach to one that provides dialogical interaction and as such would place the students at the center of the educational enterprise (Billings & Fitzgerald, 2002; Driver et al., 2000; Duschl, 1990). Observations of the 16 teachers provided evidence that teachers vary in their interpretation of dialogical discussion. The main goal of initiating classroom negotiation is to reach agreement or “taken-as-shared” knowledge, the social aspect of knowledge construction, (Cobb et al., 1992).

For four decades, science educators have been calling for science teaching reform (Schwab, 1964). The inclusion of inquiries, to promote an authentic context for students to be involved in when learning science, implies that students regain their voice in the classroom and practice not only doing science, but also thinking science. Only when these two aspects (hands-on and minds-on) are integrated, can an authentic inquiry learning environment occur. Therefore, the essence of creating authenticated learning environments is hidden in promoting the public aspects of knowledge through the negotiation of meaning (Henriques, 1997). Negotiation enables a consistent meaning to be attached to the language used by those who were involved (Prawat, 1989). Classroom negotiation would promote public aspects of knowledge, which in turn could be seen as a process of “overcoming obstacles skillfully” (Prawat, 1989, p. 321).

Among the 16 teachers observed, only a few had promoted the public aspects of knowledge within the form of dialogical interaction and maintained the same level of
interaction throughout the entire period of time. Lemke (1990) defined several forms of classroom interaction, for instance, the initiate-respond-evaluate interaction or the IRE form in which the teacher initiates a question, the student responds, and the teacher evaluates the response to end the interaction. Such tridactic interaction was a dominant form of interaction within all of Level I teachers. Further, within this form of interaction, the student did not regain his/her role and responsibility for acting as an active learner regardless of answering their teacher's questions (Driver, 1990). In one-way interactions, teachers ask and students answer, with students realizing that the teachers are providing the valued information that they want them to know.

Teachers vary in their implementations of the SWH due to the difference in their understanding of the underpinning assumption of dialogical interaction. All the teachers involved in this study knew that when using the SWH their roles must be shifted from providers of information to facilitator of information; yet in practice many teachers tended to provide rather than to facilitate. Therefore, instead of facilitating learning through negotiation of meaning and public debate of claims and evidence, they just promoted the sharing of claims and evidence rather than facilitating the discussion of them to facilitate the taken-as-shared knowledge.

**Questioning Skills and Strategies**

Questioning is an essential skill that teachers need to develop to successfully implement student-oriented learning environment (Driver, 1990). Teachers need to improve their questioning skills and grasp deep understanding of questioning strategies to be able to create dialogical interactions and adopt the role of debate mediator during students' negotiation of meaning.
Many educators have highlighted the role of teacher questioning when shifting to a constructivist approach to support student understanding as well as to provide evidence of students’ prior knowledge (Brooks & Brooks, 1993; Penick, Crow, & Bonnstetter, 1996; Yager, 1991). Teachers need to be non-judgmental, enthusiastic, and energetic while using their questioning skills. Brooks and Brooks (1993) and Yager (1991) among other educators emphasized using questioning to promote a student-learning environment as one of the important features of promoting students’ understanding of science concepts. Further, they provided some crucial characteristics of constructivist teacher pedagogy:

- Allow students’ response to drive the lessons and seek elaboration of students’ initial responses.
- Allow students some thinking time after posing questions.
- Encourage the spirit of questioning by asking thoughtful, open-ended questions.
- Encourage thoughtful discussion among students.
- Encourage and accept student autonomy and initiative

While constructivist-learning theories argue of the importance of the questioning pedagogy in students’ learning, in practice, much research indicates that teachers do not use appropriate questioning strategies and teacher behaviors in science classrooms (Blosser, 1975; Elstgeest, 2001; Rowe, 1987). Science teachers tend to ask more factual knowledge questions, which might reflect their belief of learning as a passive activity and where teachers’ instruction is the main source for student knowledge (Schmidt et al., 1998). Moreover, even if teachers pose conceptual questions, they do not display proper teacher behaviors such as wait time, body language, non-verbal, voice and proper movement to encourage students to express their thoughts and contribute to discussion (Shymansky & Penick, 1981).
Changing modes of questioning was the biggest challenge for teachers in Level I implementation. What appeared in these examples was that using classroom notes and lecturing as in the traditional approach were much easier pedagogy than thinking about students’ prior knowledge, making connections between science concepts and their prior knowledge, asking question to help them make connections, and trying to monitor their thoughts and cognitive engagement by questions in student-centered approach.

The difference in using questioning to promote learning between teachers in Level I and teachers in Level II was obvious. While a teacher like Lucy asked more thought provoking questions, probed students’ responses, and invited other students into the conversation, a teacher like Billy asked more factual questions. Further, when he tried to ask thought provoking questions, he failed to resolve student disagreement through questioning; therefore, he used a classroom vote and was willing to provide his opinion if the students’ vote was incompatible with the acceptable scientific knowledge.

All teachers indicated an awareness of questioning associated with the SWH approach. Teachers in Level III reflected more confidence in their questioning skills and awareness of its impact on learning. While Lucy stated that, “my questioning becomes richer as I help the students answer their questions themselves” (Que), which clearly reflected her understanding of the role of questioning strategies in promoting student learning, John’s response indicated constant concerns of his questioning as a main source for motivating student thinking and understanding; he stated that he wanted “to become better all the time at questioning and focusing on what is really important for students to get out of the course” (Que).
On the other hand, responses obtained from teachers in Level I, although implying their awareness of questioning, also indicated their struggle to understand and use questioning more appropriately. Rose, for example, believed that she developed her questioning skills for being able to "getting information out of students without telling them" (Que). Billy, on the other hand, who was ranked in a transition phase between Level I and II was aware that his questions were aiming for factual knowledge, which hindered student dialogical interaction meaning that he needed to develop "probing questioning skills. To help the students become independent learners" (Que). The case that the researcher is arguing for is that all teachers involved in the study were aware of the role of questioning, but the variation within their understanding of the associated pedagogy, strategies, and teacher behaviors was the source of the difference in their implementation.

**Teacher Understanding of Content Knowledge**

The teaching of science is very often a process in which the scientific concept is rarely emphasized (Hashweh, 1986), and where teachers perceive their role as facilitating the students' assimilation of content (Smith & Neale, 1989). Hashweh (1986) suggested that in moving away from content delivery towards conceptual understanding, teachers will need to make many changes. Teachers can no longer take the role of someone who is there to dispense information "that students can absorb in a more-or-less passive manner and then reproduce at the appropriate time" (Shuell, 1987, p.243).

Constructivist perspectives of learning, as previously described, view the construction of knowledge as an active process. Blais (1988, p. 4) has stated that, "knowledge is something that cannot be simply transmitted" but rather something "which each individual learner must construct for and by himself". Therefore, the traditional ways of transmitting
does not provide adequate opportunities for students to learn about the what and how of knowledge—that is, both declarative knowledge or the what knowledge and procedural knowledge or the how knowledge are not involved in active construction of knowledge by the learner.

Although several studies have focused upon teacher implementation of student-oriented learning environment, limited studies have focused simultaneously on teacher roles, beliefs, pedagogy, and content knowledge in classroom environments (Kyle, 1994). Further, the findings from all case studies within the SWH project strongly suggested that teachers' understanding of their content knowledge influence their pedagogical practice of constructivist teaching approaches.

Humans tend to store their knowledge as big ideas rather than separate concepts (Driver, 1990; Posner et al., 1982). A nice metaphor that could describe such a notion is a colored umbrella. A big idea is like an umbrella that is made out of different colors and the crossed rods that hold the umbrella together are the connections or the relationships among different pieces or concepts. Teaching from constructivist approaches implies that teachers must concern themselves with promoting understanding of such big ideas rather than focusing on bits or parts of the colored umbrella.

Teachers, who were ranked as Level I, reflected a lack of confidence in defining the big ideas of the unit. Such deficiencies could be attributed either to the lack of appropriate content knowledge or due to the lack of perceiving the conceptual framework of unit. For example, Billy, who was ranked in the upper limit of Level I, admitted that his big ideas were drawn from the essential questions of the unit that the publisher of the science textbook provided in the beginning of each unit and chapter. He chose two or three of these essential
questions based on the "science standards and the benchmarks" and as he stated, "I would send those to you guys and then you guys would kind of manipulate it to where it would be very workable, so it's just more an inquiry type of question" (Int).

The ability to define the unit big ideas is essential criterion in defining teacher levels of implementation, because based on these big ideas the teacher would decide what activity to implement to promote learning. Another example was drawn from Danielle's case study. Danielle had been working with the SWH project staff for two years and had implemented more than three units—a unit per academic semester; however, she still struggled with defining her big ideas. This was reflected in her avoidance of implementing more than a unit per semester and hanging her struggle on the SWH stating that "the whole SWH process is time consuming and I believe it is good for students to sometimes get exposure to more topics. From there, they develop a level of understanding for themselves" (Que).

**Criteria and Models**

As stated above, the discussion in this section encompasses two models: a diagnostic model for professional development (Hand, 1996) and a constructivist teaching model (Simon, 1995). To understand the differences within teachers' implementations, the researcher attempts to relate the three levels of implementations to these two models. Adopting a constructivist view, the researcher will first provide her interpretations of the two models upon which she constructed her explanations to distinguish the levels of implementation. This will be followed by presenting evidence for each implementation level from the collected qualitative data to support her interpretation (construction).

Within the framework of diagnosing professional development model, the focus was to assess teachers' knowledge and roles (Hand, 1996). Teachers, who lack conceptual
understanding of the knowledge associated with the topic to be taught or cannot define the central ideas or concepts and their relationships to one another (Prawat, 1989), will struggle when using constructivist teaching approaches (Bowden, 1988). Those teachers will notice the discrepancy between their traditional teaching practice and the new constructivist one, however, only when they begin to “change their pedagogical content knowledge [from merely focusing on covering content] to include pedagogical concept knowledge”, a noticeable change within their belief can be detected (Hand, 1996, p. 215).

Thus, within the SWH professional development program, teachers varied in their implementation due to the interaction between their discipline knowledge, their pedagogical knowledge, and their experience with the new pedagogical approach. Hand (1996) defined four levels of teacher development associated with the implementation of constructivist teaching approaches: manager, technician, facilitator, and empowerer. Teacher’s pedagogy in the traditional teaching approach could be described as manager in which the focus is on covering the declarative knowledge—knowing *that*. Being involved in a professional development program, teacher’s content pedagogy will begin to grow from managing classroom practice to focusing on the conceptual pedagogy in which the teacher begins to integrate the procedural knowledge—knowing *how*—with the declarative knowledge. Teacher’s role within this stage could be described as technician, one who follows step-by-step procedures without being fully aware of the reasons involved, which reflects the mechanical application and the lack of understanding of the associate principle to interpret their roles.

While the third development level—facilitator—describes insufficient understanding of the interaction between conceptual knowledge and pedagogical knowledge, the fourth
level—empowerer—reflects mature understanding of the integrated pedagogies and the theoretical framework associated with constructivist teaching approaches.

Teacher development based on the Simon’s (1995) constructivist teaching model could be explained by the mathematical teaching cycle (MTC). Simon’s model emphasized the role of the teacher with respect to “the decision making” between following students’ ideas and questions away from where the classroom activity should go and posing a problem and managing the discourse to focus on specific content. Simon (1997, p. 76) stated that, “teaching is inherently a challenge to find appropriate balance between these two poles”. That is, teaching from constructivist approaches implies constant evaluation of the teacher’s conceptual and pedagogical knowledge as a result of the interactions between the teacher’s knowledge of specific topic—concept knowledge—and teacher’s hypothetical knowledge of the process of student learning,—pedagogical knowledge—on one hand, and actual classroom intervention with students on the other hand.

During the unit preparation, teachers decided on a hypothetical plan for their unit. Each teacher had to examine his/her own unit knowledge to decide the big ideas of the unit. The decisions taken reflect each teacher’s conceptual understanding. Teachers then had to examine the pedagogical knowledge associated with carrying out the unit preparation including the choice of the appropriate SWH activities to promote learning of their big ideas. The plan that each teacher used for his/her unit should not indicate a fixed path; rather, it should indicate a hypothetical path that can be modified based on the actual classroom intervention.

**Level I Implementation**

Teachers within this level of implementation lacked the appropriate understanding of
the SWH and its underpinning principles. Although the theory and necessary strategies were
discussed during the inservice workshops, teachers would not change their actual beliefs
about their roles. However, it was not until the SWH was put into practice within a unit of
their choice that the teachers began to feel the discrepancy between a traditional approach
and the SWH approach.

The qualitative data obtained for teachers in this level revealed that the teacher’s
focus was on manipulating two areas: the unit preparation and the pedagogy associated with
their role within the classroom intervention. The unit preparation indicated teachers’ lack the
conceptual view of the unit concepts. This was reflected by their inability to define the big
ideas or the central concepts of the unit. Rodney, as mentioned in the previous chapter, was
not able to distinguish between the unit’s big idea and the beginning question of the SWH
activity. Brad was another example; he framed his big ideas of the electromagnetism unit as
four concepts: magnetism, electromagnetism, electric circuits, and electric charges. After
discussing and communicating with the project staff, he framed a few questions under each
concept. Billy also lacked confidence in phrasing his big ideas as indicated above.

Further, teachers within this level were concerned with the technical implementation
of the appropriate strategies to use with the SWH. They all knew that their role was not to
dispense information but rather to scaffold students’ construction of knowledge. Rose clearly
explained her concerns with both the unit’s big ideas and the associated pedagogy indicating
the interaction between both and her struggle to make a decision. She stated that,

I had to teach and then just adapted it to SWH, because I really stress on
figuring out the big ideas, I still don’t think I had those the way they needed to
be. I don’t know I just felt that everything I taught was part of the big idea
which was okay I think, but cause my big ideas started out as questions
because I didn’t want to give the kids the answers, so as soon as we had gone
through and discussed and maybe done an SWH then I changed my big idea
from a question to a statement. And I didn’t know if I could do that. I wanted
to follow the rules but I didn’t know if I was following them or not. (Int)

According to the two models, Rose’s concern was about mastering the new teaching
approach. The interaction between both concerns revolved around herself and her role. Thus,
the decision taken as indicted in Simon MTC was not a cycle between teacher knowledge
and student knowledge, but rather it was focused on the teacher knowledge.

Therefore, the researcher claims that teachers within the Level I implementation were
in the transition phase between the manger and technician stages of their professional
development. In this transition stage, the interaction between the unit’s conceptual
knowledge and the teacher’s pedagogical knowledge was focused mainly on the teacher. The
statistical data reflected this lack of development in terms of students’ conceptual
understanding. Hence, the researcher argues that teachers in this level were not focusing on
their students’ conceptual understanding; rather, they were focusing on their roles in the
classroom when using the SWH approach.

**Level II Implementation**

As stated earlier, teachers in this level reflected more confidence in both their
conceptual and pedagogical knowledge. The interaction between the teacher’s conceptual
knowledge and his/her pedagogical knowledge shifted the concern of teachers in this stage
towards promoting students’ learning. The two teachers who were interviewed indicated
different levels of understanding of their role as facilitator. Nick, with a less mature view of
constructivist teaching, indicated his constant focus on his student learning. He stated that,

I think about what do I think is the most important? So, I start with the big idea again and I think this is really what I want to be able to come back to and then start process of elimination, well this is maybe a good activity but it doesn’t really relate to what I want the kids to know, and how does it fit in . . . I mean I really think it [the SWH] forces me just to get in the material and process it. And determine what you think is important and what isn’t. And it also gets you more prepared about the content knowledge that you are going to be teaching. (Int)

George, on the other hand, reflected a more mature understanding of the interaction between both his role and his students’ learning. He stated,

“[decision making] depends on what direction it is I’m taking either them or the class. Sometimes I have to be a gate keeper, where I just slam the door and say, “No, you’re wrong”. And sometimes they just have to accept that part because they’re going to go out on a dead end. They’re going to waste a lot of time, since time is a limiting factor for a lot of things we do. . . Other times, if there’s a larger group who wants to investigate, I’ll say, “Okay, go ahead.” And I might let them go for a little while and say, “What are you finding? What’s going on here?” And usually I know that they’re going to come to a dead end and they’re going to get frustrated. And that’s when I can come in and say, “Well, maybe you can look at it that way. Can we go this direction instead?” Other times it’s just: “Nope, this is the way it is. Accept it.” (Int)

George’s view bounced between his conceptual knowledge of the unit and the pedagogical
unit associated with it. The interaction between both challenged him to think of the decision required to help accomplish the unit goals and his student goals.

Therefore, the researcher claims that teachers within Level II implementation began to grow in their profession from the technician stage toward the facilitator stage as indicated from their composite scores in which the decision drawn from classroom intervention based on the interaction of both the unit conceptual knowledge and the teacher pedagogical knowledge was focused on the learner.

**Level III Implementation**

This level was the highest level reached in this study, with the two teachers in this level having developed a more mature view of concept and pedagogical knowledge. They knew that their plan for the unit was not fixed; rather, it was vulnerable to modification at any point according to the classroom intervention. They constantly were evaluating their plan for the lesson and for the unit. Finally, they were aware when to seek help. When describing her planning process, Lucy stated,

> *When I am planning I only start with one activity. First of all, I think does it meet the big idea; secondly, I think what questions based on this introduction can I give them, what questions will they come up with based on that, so I anticipate that way. . . (Int)*

She further explained,

> *For the big ideas I have I start with looking at one SWH, what is it that I want to start with? And then from that one based on their inquiry and based on what they answer and the questions that they have I develop my next one. (Int)*
John also asserted a similar point of the continuous change to his plan based on his classroom interaction. In addition, he highlighted the point of being in control of classroom management although using student-oriented approach. He stated, "I guess you have to be committed to the approach, so when you go in there [classroom] you have to make sure that you are not just giving up your past experiences to them" (Int).

The statistical results related to John reflected students' conceptual understanding generated as a consequence of the level of implementation. Therefore, the researcher claims that the teachers within Level III implementation began to grow in their profession away from perceiving their role merely as knowledge facilitator toward empowerer. Although they still have not reached this stage, they reflected awareness of several elements included in that stage. That is, the teachers' understanding of the interaction between the unit's conceptual knowledge and the teacher's pedagogical knowledge was indicating a focus on a bigger picture, which points toward creating a framework for a constructivist teaching approach.

Summary

The use of the SWH as an inquiry-based tool within the framework of professional development program has helped the participating science teachers applying student-oriented approaches. The interpretative case study design adopted for this study including three data collecting instruments that allowed the researcher to distinguish between three levels of implementation of the SWH.
CHAPTER SEVEN

Limitations and Implications

Limitations

In examining the limitations of this study, the researcher focused on two major areas, the limitation associated with research study and the limitations of the research design.

Limitation of Research Design

Within the research design the researcher highlighted three issues related to qualitative and quantitative approaches. Any study that involves studying human phenomenon has suffered from encouragement factors to motivate human participation. Within this study, the researcher's goal was to help teachers while implementing a unit of their choice using the SWH. However, this did not mean imposing the researcher's ideas or knowledge on the teacher; rather, this reflected teacher understanding of the new teaching approach through their interaction with the researcher.

Another limitation addressed was the Hawthorne effect (Isaac & Michael, 1977) associated with the use of new techniques. The SWH as a new instructional practice for some teachers (eight teachers out of 18 involved in the study) might indicate such effects. However, this study was conducted over a period of time, which reduced the newness effect; hence, allowing time for teacher engagement with the SWH through the implementation of at least three SWH activities. The extended contact with the new teaching approach, therefore, reduced the effect of the limitation on this study.

The third limitation to the research study was related to the quantitative design. Teachers who were using the SWH for the first time were looking for solid evidence from their own practice regarding the validity of such teaching approach. Therefore, not wishing to
throw the baby with the bath water, the untreated research design was proposed and followed whenever more than one class period existed. On the other hand, the teachers who had experienced the effectiveness of the SWH, refused to teach following the traditional approach, thus, followed one-group design. The researcher, in accepting these designs, was aware of losing the ability to conduct appropriate statistical analysis needed to triangulate with the qualitative findings. However, the main goal to help improve teaching practice was acquired.

Limitation of Research Method

The researcher, in addressing limitations related to research data collection methods, was aware of the effect of the following limitations on the research findings. The need to address the limitation related to research method was essential to ensuring the credibility and generalizability of the results. The limitations needed to be addressed were related to subjectivity, other data collected from teacher, such as questionnaire, interview, and student data, and data collecting instruments.

Subjectivity bias needed to be addressed to avoid the research ethnocentrism and perpetual bias. The long period of contact between the researcher and the participating teacher might influence the researcher's view. Addressing this, the researcher first used different data collecting instruments; second, involved multiple observers and most importantly having an independent rater to assure unbiased data. Further, triangulation considered when collecting and analyzing data also limited the extent of subjectivity.

Another limitation addressed was related to teacher interview or questionnaire data. Hence, not all teachers who participated in the study were interviewed or responded to the questionnaire items due to not agreeing or time limitation with respect to both the teacher and
the researcher. Although data collected from other teachers provided different views to provide explanation for the level of implementation, the researcher concerned that this might limit the results of this study.

Further, teacher involvement in research adds to their duties. Thus, not all teachers provided the required student scores—scores of each conceptual question and the total scores of the recall questions—due to the time consuming in recording theses scores, which resulted in the lack of conducting sufficient qualitative analysis and obtaining qualitative data to triangulate with the qualitative findings.

Limitations related to data collection instruments included the video-conferencing technology and videotape. Video-conferencing technology helped improve science teacher communications with research institution. However, this technology can be subjected to many limitations when conducting data for research. The technical problems such as unclear audio, frozen image, audio without image, or the opposite image without audio limited the observational data. Further, observing and listening to the interaction among the students and between the teacher and students were limited through video-conferencing technology due to the camera angel within the classrooms and the microphone locations. The busy jam band between 9:30 am and 2:30 pm added to the above difficulties and also limited this use of such technology; hence, most science classes were taught within this period. Another limitation of using video-conferencing technology is the high speed band that the researcher’s institution had compared to the one small school used. Further, the firewall that some schools used prevented the dial up communication.

Although having videotapes of classroom interactions provided documented materials for the researcher, such methods were considered limited if used alone, as data collecting
procedure. Such procedure would add to the observational data if obtained while conducting field observational data (Schensul, LeCompte, Nastasi, & Borjatti, 1999) or when having more than an investigator involved. Within this study, the use of videotapes although served as data triangulation strategy, it hindered the instance feedback to the teacher and the expected benefits of the professional development program. Further, merely depending on such procedures did not help build trusting relationships between the teacher and the researcher regardless of the electronic mail communication. Such trust was considered essential to motivate teacher readiness to use the approach. However, the further distance from the research institute, limited the personal interactions with the teachers. The researcher, in addressing the above difficulties, aimed to assure that such technology needed to be use in conjunction with on-site (field) observation as in this study.

Implications

The results of this study provided a number of implications that could be categorized in two branches within the field of science education: implication for inservice science teachers program and implications for science teachers.

Implication for Inservice Program

Two implications within this category were suggested. The first was the use of the SWH as an inquiry-based approach to promote student learning of scientific concepts within inservice science teacher programs. The long term involvement with the SWH tool within the inservice program and providing teachers with support, strategies, and feedback would provide more opportunity for them to build their understanding of the underpinning theory of the SWH tool and enable the translation into practice.
The second implication highlights the importance of scaffolding science teachers’ practice of the new teaching approach. Teachers who had followed the researcher’s suggested strategies and feedback demonstrate progress with their SWH implementation in terms of scaffolding students’ sharing and discussion of their ideas and scientific concepts with other students. In spite of the variation within the teacher rankings, the effectiveness, although appeared slow, is progress.

Implication for Science Teachers

The main implication for science teachers is to be actively involved within inservice programs that provide them with opportunities to reflect on their current practices through the implementation of a unit within their area of science expertise following a new teaching pedagogy. The SWH, as an inquiry tool, centered on creating authentic science teaching/learning environments required teachers to adopt certain roles to be able to allow students to ask questions, invent investigation procedures, and argue their claims and evidence. To be able to adopt such roles and apply it in their classroom, teachers need to be actively engaged with the inservice program. Teaching does not imply to stop learning.

Summary

The case study approach adopted within this research allowed for evaluating of teaching instructional practice while applying new teaching approach. By recognizing the limitations of the study, the results had implications for science educators associated with the inservice education of inservice teachers, including teachers themselves. The results of the study indicated that to shift science instructional practice of teacher to an inquiry-based approach required long term involvement within inservice programs.
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APPENDIX A

Name:  Date:  School:
Grade:  No. of units:  Unit(s):

There is no right or wrong answer for the following questions. All I am seeking is your opinions and perceptions about the SWH experience. Please answer the following 12 questions regarding the SWH implementation and provide thorough explanations to justify your answer.

1. Considering the different views of science, what view would match yours the most (circle one):
   a. Science knowledge is a collection of absolutely true facts gathered by following the scientific method (a series of observations followed by reasoning).
   b. Science knowledge represents scientists' best explanations generated by using different scientific methods and supported by their data.
   c. Science knowledge represents scientists' interpretation based on their thinking, investigations and personal beliefs. Everybody's ideas are "equally" right!

2. Is there a factor that influences your choice of the unit for SWH? If so, What?

3. Does the unit preparation for the SWH differ from the traditional approach? Explain

4. Does the SWH approach influence your choice of the activities? Explain

5. When using the SWH approach, does your role differ from the role in a traditional approach? If so, how?

6. Was it difficult to implement the SWH? Why?

7. Do you see a value using the SWH? How?

8. When using the SWH approach, do you feel you are in control of student learning? How?

9. By using the SWH, which teaching skills do you feel you developed the most? Why?

10. Which teaching skill(s) do you feel you need to develop to implement the SWH better? Why?

11. Teachers often use a metaphor to describe their roles in the classroom. For example, the metaphor 'an orchestra conductor' is used to emphasize that all is under teacher control. What metaphor would you choose to describe your role in a traditional science classroom? Please Explain it

12. What metaphor would you choose to describe your role when using the SWH approach? Please Explain it

Name: District: School:
Discipline: Grade: Semester:

1. Was it difficult to implement the SWH? Why?

2. Do you see a value using the SWH? Why?

3. By using the SWH, which teaching skills do you feel you developed the most? Why?

4. Which teaching skill(s) do you feel you need to develop to implement the SWH better? Why?

5. Avoiding the educational terminology, teachers often use a metaphor to describe their roles in the classroom, for example, ‘orchestra conductors’ to represent their role in controlling the direction of student learning. What metaphor would you choose to describe your role (When not using the SWH) in a science classroom? Please explain your metaphor.

6. How would you compare it to a metaphor that describes your role when using the SWH?

7. Considering the different views of science, what view would match yours the most:

   a. Science knowledge is a collection of absolutely true facts gathered by following the scientific method (a series of observations followed by reasoning).

   b. Science knowledge represents scientists' best explanations generated by using different scientific methods and supported by their data.

   c. Science knowledge represents scientists' interpretation based on their thinking, investigations and personal beliefs. Everybody's ideas are "equally" right!
APPENDIX B
Other Unit Details
Boone Public School District

John
Second Unit: cell
John centered the Cell unit was on the following big ideas:

- Basic unit of structure and function for all organisms
- Cells are the same but have some differences
- Cells must transport across cell membranes

Three SWH activities are implemented in this unit, comparison of four cell slides, an egg as a cell, and movement through the cell. The first SWH focused on comparison of cell structure; the second is about the cell function; and the third is about osmosis and diffusion.

The conceptual questions for the unit were

1. Suppose you make an artificial cell and place 100 ml of water with a 10% starch solution inside. You place this “cell” into a beaker that contains 100 ml of water and 20 drops of iodine.
   a. What will happen to the amount of the water in the beaker and the amount of water inside the cell?
   b. Describe the movement of the particles of iodine and starch.
   c. Describe the color of the water in the beaker and the starch solution.
   d. When the cell and the solution reach equilibrium, in which direction will water molecules be moving across the cell membrane?

2. Often when a person is ill they need intravenous transfusions of liquids. Why must the person never be given pure water intravenously? Be sure to explain your answer in full, using the concepts of diffusion and osmosis.

3. In an effort to preserve cucumbers a foods class is experimenting with different solutions. They place cucumber slices into solutions of honey, salt water, and distilled water. Based on your evidence, predict what the effects of each solution will be on the cucumber slices. Which do you think will preserve the cucumbers best?

Third Unit: cell energy

The third unit, cell energy, was taught in three weeks. The unit was centered on the following big ideas:

- Organisms (cells) need energy:
  Where does it come from?
  How is it produced?
  Do all organisms (cells) need the same kind of energy?

- Organic compounds supply energy
- Enzymes are organic compounds that catalyze reactions
- ATP energy for all organisms (energy in food)
- Processes that make food and energy are complementary
  Photosynthesis
  Respiration — aerobic and anaerobic (fermentation)

Three SWHs were implemented to promote learning of the big ideas. The first SWH was about enzymes in which students explore the action of enzymes on some selected
compounds. The second SWH was about photosynthesis testing. The third SWH was to demonstrate the affect of exhaling in bromothymol blue in which students were asked to carry out an experiment with yeast, sugar and bromothymol blue. The unit assessment test included the following conceptual question:

1. Make an analogy that compares how your car burns gasoline for energy and how cells "burn" food for energy.
2. In certain ways the cellular processes of photosynthesis and respiration complement each other. Argue which process would be most affected without the other.
3. Earlier this school year many of you identified producers in your biome as the most important organisms. Visualize what life would be like if biomes did not include these photosynthetic organisms.

Fourth Unit: genetic

The fourth unit, genetics, was centered on one big idea: Heredity is influenced by genetic material, which comes from the parent(s). Three SWH activities were implemented: A comparison of mitosis and meiosis, Mendel's laws of heredity; and the structure and function of the DNA. The unit implementation lasted for 5 weeks. The unit conceptual questions are

1. Make an analogy between the nucleus of a cell and an assembly line of a factory.
2. Tongue rolling is a dominant trait in humans. In this scenario let us say that you can roll your tongue, three of your siblings (two brothers and a sister) can roll their tongues, while one sibling (a brother) and your mother cannot. How would you explain the genotypes and phenotypes of your family to someone?
3. How could changing a DNA code be compared to changing a blueprint for a new building?
Gary

Second Unit: cell

For the cell unit, although the two teachers used the same big ideas and conceptual questions, they implemented different activities for the unit. The unit implementation lasted for 4 weeks in which Gary implemented three SWH activities: a comparison of four cell slides, the egg lab, cell organelles poster. The first activity was the same as John. The second activity was to demonstrate the movement of fluids in and out the cell. In the third activity, the students developed a poster making an analogy of cell organelles to their school.

Third Unit: genetic

The genetic unit was taught in 5 1/2 weeks. Gary also centered the unit on the same big idea as John. Two SWH activities were implemented: Mendel’s laws of heredity in which students focused on the inheritance of a trait; and the structure and function of the DNA. The unit assessment test included the following conceptual questions:

1. Example 1: when Mendel crossed purple flowered pea plants with white snapdragon plants, all of the offspring were purple flowered.
Example 2: if you would cross red snapdragon flowered plants with white snapdragon flowered plants, all of the offspring would be pink.
How would you explain inheritance in peas and snapdragon for flower color through the F2 generation? Use punnett squares and interpret the results.

2. Tongue rolling is a dominant trait in humans. You can roll your tongue. Three of your siblings (two brothers and a sister) can roll their tongues, while one sibling (a brother) and your mother cannot. Explain these characteristic using biological terms such as genotypes and phenotypes of your family?

3. Part of the DNA sequence for normal hemoglobin in human red blood cell is: GGG CTT CTT TTT. The same sequence in sickle shaped cell is: GGG CAT CTT TTT.
How would you explain to a class of students that this small change in the DNA base sequence causes someone with sickle shaped cells to be short of breath?
Danielle
Second Unit: physical properties

Danielle was able to limit the unit to one big idea—that is, for a substance to change physical state, there needs to be a change in heat energy of the system. This occurs without a change in the temperature.

Danielle used four activities: evaporation of alcohol or POE activity, candle observing, phase change in water, and the slime lab. The unit conceptual questions were

1. You are shopping for a gift for your mother and looking for a nice glass figurine for her collection. The salesperson is encouraging you to buy the more expensive piece, explaining it is a "crystalline glass" and the other is not. Explain whether the salesperson is telling the truth.

2. The teacher smells cucumber melon scent in the classroom. The teacher wonders, who is doing their "personal grooming" during physical science class. Tell why the teacher will have difficulty figuring out where the smell is coming from.

3. You go home after school and make yourself a grilled cheese sandwich. As you are cooking your sandwich you notice the cheese running out the side of the bread. Explain why the cheese does not keep its original shape.

4. You and your brother are making macaroni and cheese after school. Your brother tells you to be careful taking the lid off the boiling water because the steam causes a worse burn than if the boiling water spilled on you. Do you believe your brother or not? Explain your reasoning.
Billy

Second Unit: machines, work, and energy.

The second unit was implemented in middle of January and lasted also for 5 weeks. For this unit, Billy asked for feedback on his big ideas and conceptual questions. His original big ideas for the unit were:

- Compare the different forms of energy and describe the various energy conversions
- What are the differences between kinetic and potential energy?
- Science math problems of work
- Perform experiments of simple machines

Explaining that a big idea indicates an umbrella for a cluster of concepts or a main concept that if learned a student can attach other concepts to and move on, the project researcher assistant confirmed that a big idea cannot be a question. Further, the first idea, the way it is phrased indicates more an activity rather than an idea. Therefore, Billy received the following feedback electronically:

- There are different forms of energy; each form of energy can be converted into the other
- Under "ideal" circumstances the total energy is conserved indicating a relationship between potential and kinetic energy
- Energy changes (in form or intensity) because of work
- Simple machines are examples of energy form conversions

As for the unit conceptual questions, Billy also came up with the following three open-ended questions:

1. What is the relationship between work and energy?
2. How are work, power and energy calculated?
3. Identify and compare the human body to levers?

After agreeing on the last and rephrasing the first two questions, the machines, work, and energy unit assessment test included the following conceptual questions:

1. John is flying a kite and suddenly he pulls the string down by moving his arm a couple of inches. Do you think that will be any change in the energy of the kite? Why? If there is a change, please describe it?
2. Now Tom and John are racing with their kites, they start with their kites on the ground at rest and both are facing the wind in the same way. John runs for three minutes, while Tom runs for five minutes. What do you expect to be the final velocity of the kites? Please consider all the possibilities.
3. Identify and compare the human body to levers?

The second unit covered Work and Energy. In this unit, Billy implemented two activities. The first activity targeted the essential question of what is work and how do we measure work. The students were asked to pick a sport where the athlete did the most work and be able to support their position. The second activity was to promote learning of energy. Students were building of a lou-vee-air car that will travel a distance of two meters. The focus of the activity was on showing that energy could be stored in the rubber band operated motors until released of the propeller for potential energy to be transferred into kinetic energy.
Nick

Second Unit: classification

Nick limited the unit to the following big ideas:

- Classification is a system of sorting based on similarities
- Organisms are classified mainly by structure and function
- Organisms are classified into seven levels including a scientific name, which is unique to each organism

Three SWH activities are used for the unit: classification system, Shark Dichotomous key, what is your dichotomous key. In the first activity, the students were involved in classifying and naming 20 common objects (provided). They were to divide the 20 objects into two large groups and each large group into 4 smaller groups. Further, the students involved in a debate with others to defend their separation and classification of the objects. In the second SWH, the students used a given dichotomous key to classify 14 different families of sharks. In the third activity, however, the Students created their own dichotomous key using a group of similar objects that they are interested in, e.g. CD's, DVD's, toys, food, stuffed animals, sports cards, books, etc. The unit evaluation test included the following conceptual questions:

1. If you had to explain to Aristotle how classification has changed since his time, what would you tell him?
2. Taxonomists classify animals down to the level of species. Argue why they should do this, rather than only classify down to the genus level. Give examples when necessary.
3. Why do scientists find it useful to have a consistent system for classifying living things? What might occur, if it was not consistent?
4. Given the following group of organisms, create a classification system and write a paragraph justifying your groups.

Nick accepted the researcher suggestion to omit the first conceptual question from the unit assessment test because of its duplication to a writing assignment that he intended to give to his students after the third SWH activity—write a letter to Aristotle describing how the modern system of classification differs from his system.
Second Unit: Nutrition (Dairy Council Rat Project)

Lucy chose the following big ideas:

- There are five basic food groups in the food pyramid.
- A healthy diet includes food from all food groups eaten in moderation.
- The body uses nutrients to provide energy, and to build and repair body tissue. Calcium and Vitamin D are essential throughout your life.
- Moderation and balance in food and exercise are the keys to good health.

One SWH activity was implemented in which students chose to answer this question: Which foods have sugar in them and which foods have the most sugar in them? They used clinistix to test and answer their own questions. As for the unit assessment test the unit required that the teacher use the Dairy Council’s pre and posttest. Therefore no conceptual questions were added to the test. The implementation time of the unit was approximately eight weeks.

Third Unit: physical science/work and machines

Lucy centered her third unit, which lasted for four weeks on the following big ideas:

- An object stays at rest unless some force puts it into motion.
- You are in motion when you move from one position to another.
- Pushing and pulling can change the position and the motion of an object.
- Work is done when a force moves an object.
- Machines make work easier by increasing the force or changing the position of the force.

Two SWH activities were implemented. The first one was to answer the question: How can you lift Mrs. Huckleberry with only one hand? The second SWH was centered on the idea of load and effort. The unit assessment test includes the following conceptual questions:

1. Explain how pushing or pulling an object can change the position and motion of an object. Think in terms of how this can help you in real-life situations.

2. You are working on a farm. Your task is to move 200 large bricks from the shed to the side of the barn to build a new retaining wall. Your dad wants you to move these bricks by lunch so that he can work on the wall in the afternoon. Explain the easiest way that this could be done if you were working alone.

3. When you were in the classroom, you put your science book and a pencil on your desk. You left to go to lunch. When you came back from lunch, your science book was inside your desk and your pencil was on the floor. How did this happen? Answer using what you know about physical science.
Des Moines Public School District

Sondra
Second Unit: genetic

The implementation of Sondra’s second unit (genetics) began in Mid December for approximately 5 weeks (with a 2 week holiday break between the first and second weeks of the unit) in which Sondra focused on the following big ideas:

- How Mendel’s studies of inheritance and probability apply to organisms.
- How proteins are assembled in cells.
- How genetic traits and diseases are passed down from parents to their offspring.

In this unit, Sondra implemented two SWH activities. In the first activity, the banana lab, the students focused on what DNA is, where it comes from, and what it looks like. The second SWH was the Duchenne muscular dystrophy activity in which students were asked to respond to the following question:

Billy and Lola got married last year and are interested in starting a family. Lola's family has a history of carrying or having the Duchenne muscular dystrophy allele. What are Billy and Lola's chances of having a baby with Duchenne muscular dystrophy?

The unit assessment test of her students' conceptual understanding includes the following conceptual questions:

1. In sheep, the allele for white wool (A) is dominant over the allele for black wool (a). Explain in writing how you would determine the genotype of a white ram, or male sheep. (You may also use punnett squares to help explain your answer.)

2. Is photocopying a document similar to DNA replication? Think of the original materials, the copying process, and the final products. Explain how the two processes are alike and how they are different.

3. Explain the similarities and differences between DNA and RNA. Be sure to include at least 3 comparisons in your answer.

4. Two prospective parents learn that they each carry one allele for Tay-Sachs disease. Why does neither of them suffer from Tay-Sachs disease? If they decide to have children, what are the chances they will have a baby with Tay-Sachs disease? What are the chances that one of their healthy children will carry the Tay-Sachs allele?
Ames Public School District

George & Roger
Second Unit: cell

The cell unit implementation began directly after the ecosystem unit starting at the end of November and ending in the middle of January, lasting for about six weeks. George and Roger decided to center the unit on the following big ideas:

- How do substances move in and out of cells?
- How do plant and animal cells produce usable forms of energy?

In addition to the cell shape, three SWH were implemented in this unit: iodine activity, egg activity, and the elodea.

The cell shape activity focused on observing different fruit and vegetable cells under the microscope to recognize the similarity and differences in plant cell. The first and second activities were based on introducing some functions of the cell component and mainly focused on distinguishing the difference between diffusion and osmosis. The third activity, elodea, is focusing on photosynthesis and respiration of the cell. George and Roger chose to include the following conceptual questions in their cell unit assessment:

1. We know that living things need to use energy to grow, reproduce and live. Describe how plants capture and use energy. Don't forget to clearly explain, in detail, your thinking.

2. Thinking back to our labs, observe the following pictures. There are red blood cells in each picture. Letter A is a normal blood cell. Explain what you think has happened to the red blood cells in picture B & C and why it occurred.
Feedback to Danny on the 2nd SWH implementation Dec 3, 2003

Hello Danny,

I really enjoyed observing the SWH session on Wednesday Dec 3rd! The kids were on task and interacting with each other. Below are few points that we discussed afterward.

Setting the problem context was effective in raising students' curiosity. The beginning questions asked were more open-ended. When it comes to sharing, however, we need to remind ourselves that they are fifth graders and still working on their writing skills. The SWH approach, as you know, is a student-oriented approach that integrates reading, writing, and authentic scientific inquiry. Students will benefit from further discussion to the beginning questions and ideas. So, we can ask them to group the questions written on the board. This step will promote the discussion of whether the question asked is testable or not and how can we design an experiment to test each question. Such discussion is beneficial to promote learning about the nature of science.

We always need to remind ourselves not fill in the blanks in student’s response. Why questions are very important to student metacognition. Asking ‘why do you think that?’ will encourage the student to think, elaborate, and provide reasoning for the idea under discussion. The reasoning that a student provides will help us, teachers, to not only construct ideas about student knowledge, but also to diagnose the weakness (or strength) within student ideas. Moreover, inquiring more about student’s idea will promote more dialogue in classroom, which will invite other students to participate and share their ideas.

In such context, teacher’s verbal and nonverbal are crucial in promoting or shutting down the dialogue. For example, providing judgmental statements gives the impression of authority figure in classrooms and students definitely will hesitate to share their true ideas and beliefs.

The final point that we discussed was regarding claim and evidence. We discussed how to promote more dialogue within the discussion of different groups’ claims and evidence in which each group will share with others the beginning question, experiment, observation, and claim, which is a statement of knowledge. We also highlighted the point that evidence is not merely to site the observation and talked about the components of more powerful evidence in which students reason how they reached from observation to their claim providing some connection to prior knowledge. We emphasized the point that data do not spoke of themselves and we need to interpret them in a way that makes more sense to us.
Feedback to James on the 1st SWH implementation (videotape observation) 10/22/03

Hello James,

Sorry for being too late to get back to you with this! I just got the first session videotape yesterday. I enjoyed observing the session; the students were engaged in the discourse and enjoyed it. Also, good class management and use of nonverbal. Below I highlighted few points that I wish to further discuss with you:

1. **Small group discourse**
   - The strategy you used to divide the students into groups was good, but I wonder why did you choose to divide them into 3 groups only?

   While students were engaged in small group discussion for 10 min, you were going around listening to their discourse and sometimes interact. How did you decide when to interact with their discussion and when to just listen? Also, I’ve noticed that you interacted more with one group compared to the other two (unfortunately I couldn’t hear the discourse that took place) Why?

   You extended the discussion time 10 more min (why) and what makes you decide to move to large group discussion?

2. **Large group discourse**
   - Within the discussion, you took vote, but you didn’t tell the students your opinion, why?

   The discussion of the session was focused on agreeing upon testable questions vs. not. When discrepancy occurs among students, you took vote as means to decide and go with the larger vote. How about if we ask the groups to be involve in an argument or a debate in which each group explain why did they say so and what’s their reasoning. Also, they would have the chance to reflect on other group’s idea via highlighting weakness in their reasoning. This will model to the students the scientific argumentation and promote features of the nature of science. Please let me know what do you think?

   I’ll observe the second tape over the weekend and get back to you no later than Monday.

   Have a nice weekend!
Feedback to Matt (classroom observation on Feb the 16th, 2004)

Thank you for inviting me to observe your classroom today!!

You seem to have good, nice, and polite students. I’d like to highlight few points by asking some questions about what I’ve observed today. The SWH rubric that you used is very effective in encouraging students to respond more effectively and involve in the SWH process. Also, the way you walk them through the rubric, to me, was efficient in drawing their attention.

You pointed to the richness of information provided in the SWH reports. I agree that the more rich and elaborated the writing is not only the better their learning, but also what we (teachers) know about their learning.

The example you provide to students about the test section of the SWH and how if the high school students (audience) will not be able to repeat the experiment. What does this point indicate about the nature of science (NOS)? Why is it important to repeat the same test? We can ask students more questions which will promote learning about the NOS. I am not quite sure that I understand your point view regarding the reading section. Yes we are looking for more elaboration in the student writing, but I got confused about if the student idea is incompatible with the book idea and how to view this.
Feedback to Rose on her 1st SWH (videotape observation: Jan 21, 2004)

Dear Rose,

I am so sorry that I forgot to get back to you soon!!

The activity choice is good to focus on the big idea, which I assume is the magnetic field (power, please let me know if I not correct). Students were working collaboratively in groups and the way you asked them to put their disks back is good for fourth graders to interact more in their small groups.

You asked and explored about students prior knowledge (although the audio was not clear enough to hear your questions). The interaction that took place was mostly one-on-one in which you initiate a question, a student respond, and you evaluate the response. What if instead of evaluating this one response of a student we asked the other students of what they think. If they couldn’t hear the first student can simply till them his or her answer.

There are at least three advantages that I can think of at the moment of stepping back from evaluating student answer. First: all students will always pay attention in the class, think, and evaluate each other. Second: they will learn how to interact and respect each others. Third: besides giving us some time to think for another question to ask to students, this provides us with an idea of what students know and how they think.

For this young age, curiosity works very good to motivate learning. We can just provide a context of a problem and by using questioning they can come up with several questions about the problem that they want to answer. Allowing student to ask their own questions initiate their curiosity. Also, together, they can discuss which questions are testable and which aren’t. They need to provide logic reasoning for their answer in which other student may reflect upon. Then we can move to which question can be tested in our classroom and what materials we need to do this. This will also give us a chance to invite them to think of issues related to the nature of science (NOS) such as how do scientists know? What is an experiment? What are observation, claim, and evidence?

I’ve noticed that you asked each group to write their claims on a colored sheet for sharing with others. Toward the end of the session you asked why the wand magnet is most powerful and how can we test. I wonder if this will be revisited the next time.

Nice class management!!
Feedback to Rodney on all his 3 SWH implementation (Matter)

Thank you for sending your SWH tapes! I got the chance to observe them and made a copy. I sent them back to Kim today. Please find below few suggestions for future implementation.

The SWH approach is derived from student-oriented approach. Although this approach put more emphasis on students as learners, the teacher role is crucial in promoting the context for learning. This why the SWH has two templates: a student and a teacher. Without promoting the suggested teacher activities in the teacher template, the SWH loses its significant value and becomes more as a different writing format for an activity report.

Thus, the big ideas we want students to learn, the activity we choose to promote the big ideas are very important steps in the unit preparation.

In the first SWH I observed, you provided beginning questions for the activity: Is the substance a solid, liquid, or gas? How are molecules moving? You provided materials for the students to use and the substances to investigate. Posing the question and leave the procedure for them to create to answer the question is good. Yet, ask them about their thoughts (ideas) and their questions regarding the topic are very beneficial. Through our interaction, we can learn about their prior knowledge. Also, asking them to generate questions will raise their curiosity and challenge their thinking of how to answer the questions.

From where the camera was located, I couldn’t see much of student investigation. I wonder how did they answer the second question: How are molecules moving? What type of activities did they do? What questions you were asking? Have you discussed with them in advance the prosperities of different states of matter?

Your second SWH, the Oobleck, is pretty much the same as the first SWH. I wonder what big idea you are promoting from these two activities. What are some examples of students’ claims and evidence?

In the third SWH, you also provided the beginning question: Can we trap a gas? This question implies yes/no as an answer, while the SWH pushes for more open-ended question that will promote student interactions and challenge their thinking.

What big idea you intended to promote by this activity? What were the students doing to investigate besides putting the balloon over the bottle? What are some questions you were asking?

Toward the end, you asked few questions: how did you keep the gas? How do we know it’s a gas? What happen that make you say there is a gas? These are good questions to motivate student thinking. If we cannot see something that does not mean it’s not existed (I agree). Also, if we see something (observation) we need to make effort to interpret what we saw (data never spoke of themselves). Yet, the main idea of the discussion of claims and evidence is to share the meaning students generate from the activity and attempt through the discussion to relate or connect this meaning to the big ideas.

I looked through the papers Brad brought back with him; I couldn’t find any student SWHs. I was anxious to read some of their claims and evidence, the tests they created, and their reflection sections.

I hope that you agree with me that we need to create more discussion with and among students. Always ask for elaboration and seek others reflection. The most important is ask more what, how, and why questions.
Feedback to Rachel on the 1st SWH implementation Dec. 1, 2003

Thanks for allowing us to observe your first SWH session today. It was interesting seeing the kids engaging in the activity. I am writing this email to further highlight a few points regarding the first observation, so I hope to hear from you soon!

The first point that I would like to open for discussion is the difference between the SWH approach and the traditional teaching approach.

- What differences do you see between the two approaches? Why?
- What differences do you see in students’ reactions to the approach used? Why?

As you know, the basic idea behind using the SWH is to allow students to have a major role in their learning and to find a connection between school science and everyday life. Such a connection will be easier to build if we motivate their curiosity regarding the inquiry via taking leadership of the beginning question and allowing them more time to discuss, comprehend and share ideas. The beginning questions they will ask about the investigation will be reflecting their level of knowledge and will enable them to make the connection to the new knowledge claimed from the activity.

Also, it is good that you direct the students to make a prediction before the activity, so they can discuss in more detailed within their claims and evidence section why did they predict this? What happen? What occurred so that they could make a prediction and why? What did not and why? What are some more inquiries that they might do?

The second point that I would like to open for discussion is regarding the process of the investigation. I’ve noticed that you provide them with a common question (what would happen to the raisins if put in water?), but this was not followed by other questions. For examples, what are some other questions that they might ask? How can we test them? What are the variables we have? How can we control those variables? Why is it important to control variables? For a seventh grader it is very powerful to discuss variables and controlling of them so they realize that there is not one scientific method to follow and it is scientists (investigators) who create their own experiments and control their variables.

Another suggestion that we might consider in the next SWH is regarding the sharing of claims and evidence. Each group can share their claim and evidence with others based on their beginning question and experiment they did. Other students can ask questions and reflect on their claims and evidence whether they agree or disagree and why. Such a discussion will allow students to understand more about the nature of science and seeing the differences in experiments, yet we still can reach up to similar claims. Or if the results are not sufficient enough to draw a claim and more inquiry are in need. One of the difficulties when holding these types of discussions is that they take a little bit of time. There is always a balance between telling and allowing students to construct their understanding. The importance of the discussion I believe outweighs some of the disadvantage of the time factor.

The final concern is regarding the difference between osmosis and diffusion; how would the student realize the difference between the two from the activity? I am sure that we agree that we want them to distinguish both without us passing information to them.

Thanks!
Feedback to Sondra on the 1st and 2nd SWH videotapes (Nov 4 and 13, 2003):

Hello Sondra,

I enjoyed observing the two videotapes. I found it interesting that each teacher choose different activity to the same concept, which I need to think of before I open it for further discussion. Below are two common points from both videotapes that I’ll be glade to discuss with you.

The first point that I’d like to highlight is the importance of creating dialogical discussion in classrooms regardless of the teacher involvement or not. The SWH teacher template encompasses several negotiation or dialogical activities in different phases of inquiry. Let us first think of: why is it crucial to promote dialogical interaction in classroom? What learning theory is the SWH support or driven from? And how can we implement student-oriented approach?

The above questions lead us to discuss our role in the learning context and force us to define dialogue or dialogical interaction. A dialogue, as I see it, is a more open-ended conversation. To promote it, means to ask questions, seek elaborations, and create non-threatening learning context. A common way to create a dialogue is to ask question to student and follow the response by seeking elaboration (why). This is a short version of dialogue, since it will end by the second or third response and involve two parts only (the teacher and one student). We need to invite other students to the dialogue by seeking their ideas and reflections. This is really the essence of implementing the SWH. I’ll leave this open at this point to further discuss after I know you reflection.

The second point that I’d like to highlight is regarding claim and evidence. Telling the students that “evidence is what you saw or you didn’t saw” is kind of a misleading statement. Evidence is not merely to site the observations. We need to remind ourselves that data do not spoke of themselves and we need to interpret them in a way that makes more sense to us. While claim is a statement of knowledge, evidence should include other components to be more powerful in which students’ reason how they reached from observation to claim providing some connection to prior experience and/or scientifically acceptable knowledge (you may want to read Driver, et al., 2000; article attached).
Area Educational Agencies Observational Notes

Area Educational Agency 13
Teacher: Lucy

Review of big ideas.
K-W-L on work (Getting at prior knowledge/public notes on board—Excellent way to help students gain ownership of ideas)

What I know:
- Work is done when a force moves an object
- Work is sometimes hard
- You can make work easier with machines
(Are you in agreement with this statement??—Builds consensus with kids—Goal would be to get kids to question/defend one another—talk to each other—student discourse)

What I want to learn:
- When you work do you always change position?
(I’m going to give you two minutes to talk in your groups about work and come up with questions—gives everyone a voice)
  - How do you know if work is being done?
  - What is the average time you work a day?
  - Do you work all the time?
  - How many times do you work a day?
--Let’s think about these. Is that a testable question? Think and search? Researchable? What are we thinking?
--How can I find out the answer to that question?
(Integration of reading strategies—you are so amazing!

How can you lift me with one hand????—Writing on template
--Look up here because I don’t want you to forget something. I want you to tie this back to this one more time. You gave me a good list of questions. We agreed one could be tested. This is your challenge—how can you lift me with one hand. What is your next step? TEST.
Use this paper to jot down notes and draw a diagram of how you think you can lift me with one hand. There are materials in this room that might help you. I’m going to give you ten minutes on you are going to test it. Raise your hand when you have an idea and a diagram drawn. Safety!

--Taking a yardstick and hitting me on a body part to make me jump does not count!

--“I’m listening, talk to me about what you’re doing”

--“What is going to happen? Can you draw that? Can you write that down as a test?”

--“You were working with something over here—and I thought I saw a good idea.”

(Kids are excited and talking—100% engagement!)
--“What are the objects you’re using, you need to tell me that”
"Think about what you’re learning from the groups that you’re seeing so you can tie together your idea so it can become a better idea."

Tables started considering safety issues! Neat!

--“Everybody stop and take a look. They have three boards—where do you want me to stand?
--Thumbs up or down—is it safe?
--Let’s listen to groups that have their tests written down—questions for her about her test”—WOW! Encourages student discourse!!

Kids
--she stands on that side
--No—she stands on that side
(deciding where to put the fulcrum)

--“Why won’t that work?? Think about it!!”
--“It didn’t work—let’s think about this. That worked, this didn’t—what conclusions can you make?”
--“you decide as a group”
--“Scientists don’t quit, they keep going. They change the variables. What are the variable of this experiment?”
--“Did this experiment work? Write down what you found out.”

Michelle—What did you change from the first time to the second time? What else could you change?

Kids
--it’s about 6 ½ feet
--where should she stand?

--“This group said something interesting that you might think about. Thinking about what you know about force, mass, and work where do you want me to stand?”
--“Did it work? Back to the drawing board.”

EVERY group is still talking science with excitement. (11:00 a.m.) They are constantly debating what is going to work or not work. GREAT amount of discourse happening in each group.

--“This is an interesting twist-watch and learn.”
--“Explain what you want me to do and why?” “Wow—this is really interesting. Even though this group is working on the floor, part of this group is working at their desk (on a model)”
--“Now I have a question for you. What is the purpose of the extra piece of wood? What if you didn’t have the extra piece of wood? Would it make a difference? How did you figure it out? (By using a smaller scale model)—AWESOME!!
MORE STUDENTS NOW USING MODELS TO TRY OUT THEIR TESTS! (11:08)

--Your claim has to do with....?
--“Let them explain..” Other kids want to critique their test immediately!
"Show me"

YOU DO AN INCREDIBLE JOB OF COACHING THE KIDS AND ASKING QUESTIONS INSTEAD OF GIVING ANSWERS!

"We are going to share tests/observations."

One student describes to another group what their observations should tell/explain.

Questions for this group—they are looking at the teacher—try to encourage them to address the person speaking.

Encourages kids to revise/add to their tests and observations to be more complete.

When writing a claim think back to your question and big ideas.

--What is your evidence?? What happened??

--What did you do?

--Thinking about that in terms in science....

Claims

We used a board that acted like a machine. --questions for them

What machine is like a board—addressed to teacher

A jack—we pushed down and you went up

If you put the block in the middle of the board it will NOT pick the teacher up.

Why won’t it—because we tried it and it didn’t work, you have to put it farther than the middle

We used a machine to decrease the work.

How is the board a machine?

It was like a lever.

Like a teeter totter

"Write down claims and evidence as a group because we are going to read about the science of this before lunch."

"How do my ideas compare with others???"

Board acted like a machine and decreased the work

Board acted like a machine

We used a machine to lift up Mrs. Hockenberry

What were the bearing or lubricants in the machine?

The little tiny block thing. "Is the block a bearing?"

"is there a bearing in this machine?" No

"Are your ideas the same as others or different than others?"

Handed out information sheets

"What did you learn from reading?"
Teacher: Rose

Students came up with common names for magnets—great to have common vocabulary

Same
   All magnets
   Don’t attract brass, aluminum and copper
   They all have magnetic force
   They all attract something—they might attract each other

Differences
   Not all have plastic
   Different colors
   Different shapes
   Weigh different
   Different strengths “How do you know?”
     Student hypothesizes
     “I don’t know”—great not to confirm hypothesis

Student came up with question on strength—could refer to this as beginning question/ great that it is related to what we are going to study today.

Student—how will we test heavier things?
   “you decide that with a group”

“What do we need to remember?”
   Don’t put them on the computer....
   Quiet
   Don’t drop

“How do you know?”
“How are you going to...”
“What are you testing?”
“Maybe your group needs to talk about that..”
“Ok, so what is your test?”
“How are you testing the other ones?”
“What are you observing?”
“Are they alike?”
“What are you seeing?”
“Prove it.”

Great job at coaching them with questions. You pushed them to think deeper—you didn’t say whether they were right or wrong—THEY had to think!!

Idea for explaining tests and observations (Question—what is the best length of time to cook the recipe?)

Tests are like a recipe
   If you make a recipe using the exact measurements for the ingredients
   And bake at 350 for 45 minutes
Observations are what happen
   It burns
Next test
   Make the recipe using the exact measurements for the ingredients and
   Bake at 350 for 30 minutes
Observation
   It is golden and firm
Next test
   Make the recipe using the exact measurements for the ingredients and
   Bake at 350 for 15 minutes
Observation
   The recipe is still a liquid and hasn’t changed color

We only changed one thing about each test (variable) so we know what made the difference.

Claim- The best time to bake the recipe was 30 minutes. (Statement—answer to question)
   Evidence- When we baked the exact recipe at 350 for 15 minutes it was still a liquid and when we baked the exact recipe at 350 for 45 minutes it burned. Only at 30 minutes did the recipe appear firm and golden.

Related quantitative data to track—do we say we ran the race really fast? What is someone else says really fast? How do we know who wins?—that was sooo good!!!!! I could tell he made the connection to needing more accurate data!

Lots of energy and excitement in the classroom!!

You have excellent management skills!!

“The bigger the magnet the more powerful”
   “Anybody have questions for them?”
“The bigger the magnet, it will pick up more stuff” Evidence- “The washer ones didn’t pick up as much stuff. The horse shoe was the weakest”
“The bigger the magnet, the stronger it is”
“The bigger the magnet, the stronger it is”

We all agree
   “the wand picks up the most”
   “the horseshoe picks up the least”

“Did you count them?”
   “146 paperclips with the wand”

“Is there anything up we can’t agree with?”
“Is there another way we could have tested?”
   Increasing number of wand magnets
Did more experiments to have better claims and evidence—need more magnets

Back to question

“What is the strength of the wand magnet?”
Strongest of the four magnets we used

“What is the strength of the horseshoe magnet?”
Weakest of the four magnets we used

“What is the strength of the bar magnet?”
Second strongest of the four magnets we used.

Don’t let them put just “same”—make them write out what was the same—makes them articulate their thoughts in writing—that writing connection we want to make! 😊

GREAT further discussion—really led to some questions that could be answered in future SWHs if time allowed.
Teacher: Rodney

First Question—Is the substance a solid, liquid, or gas?
Second Question—How are the molecules moving?

Clap once, clap twice, thumbs up—excellent classroom management skills!!

Two cups marked with star
Two toothpicks
Two straightened paperclips

Materials there for you to use and figure out the question—Is the substance in the state of a solid, liquid, or gas?

First set of cups marked A—you figure out if the state is a solid, liquid, or gas—you’ll also have B, C, D, and E

**You might have done this previously, but I wonder if it would have helped having the kids express their ideas about what characteristics a solid, liquid, or gas that make them unique—would this help them decide what kinds of tests they could perform? It would help get an idea of their prior knowledge. OR is having them perform tests, observations and making a claim supported by evidence your way of making them articulate these characteristics?? Just a thought!

“What tests do you have?”
“What are you going to do to that? Write that down.”
“What did you do so far to this?”
“What else could you do here?”

**These are great coaching questions—you’re asking the students to think more deeply and explain their understanding

**The kids are all actively participating—everyone is on task and “talking” science. I heard several partners debating with one another who was “right” or how to write something they had learned down

**They had to write a lot today—without complaining I might add—I thought that was great

Third Question—What state of matter is Oobeleck??
Fourth Question—How are the molecules moving?

**How fun to watch them discover this for the first time! They immediately got louder from the excitement—this experience will stay with them! Brain research tells us learning is increased when emotions are involved—I think this activity really sets the stage!!

“Show me what evidence supports it if you say it’s a liquid.”
“Show me what evidence you have for a solid.”
"What evidence do you have?"

**Part of the process is having the kids share their claims and evidence publicly. You might have gone substance by substance having one partner pair share theirs and have the other groups agree/disagree with them based on their own claims and evidence. It is important the kids talk to each other instead of AT you. Then they could use this to write about how their ideas compare to others or how their ideas have changed. Also, this could be used as a purpose for their reading—ask them to read about states of matter in their textbook and compare it to the activities they did today. This is an important step—making connections between their shared experiences and the big idea.

**You have great classroom management and had the kids actively participating in the activities, which is a HUGE first step. You did SO MUCH right!!! These kids and this district are lucky to have you!
Area Educational Agency 11
Teacher: Sondra

Notes 1
During the pre-observation conference Sondra said that one of her goals was to work on more student ownership and more student to student dialog. Therefore during the observation I focused on the type of questions by counting the number to teacher to student questions and the number of student to student questions. Sondra provided time for students to share in table groups, allowing for student to student questioning. During large group time, all questions were teacher directed.

Notes 2
During this observation, I recorded questions asked during a guided inquiry activity. The activity had been set up the previous day as a homework assignment. Students were supplied basic materials and instructed to add a liquid of their choice from home and make observations. Today’s activity included sharing observations and making a prediction in small groups. Sondra provided the initial instructions and then moved from group to group.

T. Directions: Make a prediction as to what you think will happen to the shark if placed in Gray’s Lake (a small lake on the south side of Des Moines). Think about what is happening at the cellular level.

<table>
<thead>
<tr>
<th>Teacher Question/Comment</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>What is going to shrivel up?</td>
<td></td>
</tr>
<tr>
<td>How do you think it’s going to look after...?</td>
<td></td>
</tr>
<tr>
<td>What do you think its cells will look like?</td>
<td></td>
</tr>
<tr>
<td>What has this group decided?</td>
<td></td>
</tr>
<tr>
<td>What effect is that going to have on the shark?</td>
<td></td>
</tr>
<tr>
<td>What effect will that have on the actual cells of the shark?</td>
<td></td>
</tr>
<tr>
<td>OK, so you think it’s going to get mushier, what do you think, Emma?</td>
<td></td>
</tr>
<tr>
<td>So, why do you think the salt will be coming out of the shark?</td>
<td></td>
</tr>
<tr>
<td>Oh,-something to think about. I’m going to let you ponder that. Then I’ll be back</td>
<td></td>
</tr>
<tr>
<td>OK, so the cells are going to what?</td>
<td></td>
</tr>
<tr>
<td>So, we have conflicting ideas. One of you is telling me.... and one of you is telling me...</td>
<td></td>
</tr>
</tbody>
</table>

At this point the students were directed to write claims to support or dispute their predictions.

<table>
<thead>
<tr>
<th>Teacher Question/Comment</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Be specific. You can base your claims on the macroscopic level – like what it looks like. Or, you can base your claims on microscopic evidence – when you look at it with the dissecting microscope.”</td>
<td></td>
</tr>
<tr>
<td>“Think back to your egg (experiment).”</td>
<td></td>
</tr>
<tr>
<td>I think we’re confused about osmosis and diffusion.</td>
<td></td>
</tr>
</tbody>
</table>

Sondra, I’ll let you decide what type of questions you ask as you move from group to group. You seemed to be helping students clarify their thinking or just take a stand. The majority of the students in each group would happily have remained as passive listeners, unlike the other class I observed. Are there any other techniques you use to keep them all engaged?
APPENDIX D
Human Subjects and Consent Forms

TO: Brian Hand
FROM: Human Subjects Research Office

PROJECT TITLE: "SWH Partnership, Phase II"

RE: IRB ID No.: 03-139

LENGTH OF APPROVAL: 1 year CONTINUING REVIEW DATE: October 17, 2004

TYPE OF APPLICATION: □ New Project ☒ Continuing Review

The Human Subjects Review Study has been approved. Please make sure that you obtain the consent of the parents and participants before you conduct the study.

Your human subjects research project application, as indicated above, has been approved by the Iowa State University IRB #1 for recruitment of subjects not to exceed the number indicated on the application form. All research for this study must be conducted according to the proposal that was approved by the IRB. If written informed consent is required, the IRB-stamped and dated Informed Consent Document(s), approved by the IRB for this project only, are attached. Please make copies from the attached "masters" for subjects to sign upon agreeing to participate. The original signed Informed Consent Document should be placed in your study files. A copy of the Informed Consent Document should be given to the subject.

If this study is sponsored by an external funding source, the original Assurance Certification/Identification form has been forwarded to the Office of Sponsored Programs Administration.

The IRB must conduct continuing review of research at intervals appropriate to the degree of risk, but not less than once per year. Renewal is the PI's responsibility, but as a reminder, you will receive notices at least 60 days and 30 days prior to the next review. Please note the continuing review date for your study.

Any modification of this research project must be submitted to the IRB for review and approval, prior to implementation. Modifications include but are not limited to: changing the protocol or study procedures, changing investigators or sponsors (funding sources), including additional key personnel, changing the Informed Consent Document, an increase in the total number of subjects anticipated, or adding new materials (e.g., letters, advertisements, questionnaires). Any future correspondence should include the IRB identification number provided and the study title.
You must promptly report any of the following to the IRB: (1) all serious and/or unexpected adverse experiences involving risks to subjects or others; and (2) any other unanticipated problems involving risks to subjects or others.

Your research records may be audited at any time during or after the implementation of your study. Federal and University policy require that all research records be maintained for a period of three (3) years following the close of the research protocol. If the principal investigator terminates association with the University before that time, the signed informed consent documents should be given to the Departmental Executive Officer to be maintained.

Research investigators are expected comply with the University’s Federal Wide Assurance, the Belmont Report, 45 CFR 46 and other applicable regulations prior to conducting the research. These documents are on the Human Subjects Research Office website or are available by calling (515) 294-4566.

Upon completion of the project, a Project Closure Form will need to be submitted to the Human Subjects Research Office to officially close the project.
TO: Brian Hand  
FROM: Human Subjects Research Office  
PROJECT TITLE(s): “SWH Partnership, Phase II”  
RE: IRB ID No.: 03-139  
TYPE OF APPLICATION: Modification  
APPROVAL DATE: October 29, 2003  
REVIEW DATE: October 29, 2003  
CONTINUING REVIEW DATE: October 17, 2004

Your human subjects research project application, as indicated above, has been approved by the Iowa State University IRB #1 for recruitment of subjects not to exceed the number indicated on the application form. All research for this study must be conducted according to the proposal that was approved by the IRB. If written informed consent is required, the IRB-stamped and dated Informed Consent Document(s), approved by the IRB for this project only, are attached. Please make copies from the attached “masters” for subjects to sign upon agreeing to participate. The original signed Informed Consent Document should be placed in your study files. A copy of the Informed Consent Document should be given to the subject.

If this study is sponsored by an external funding source, the original Assurance Certification/Identification form has been forwarded to the Office of Sponsored Programs Administration.

The IRB must conduct continuing review of research at intervals appropriate to the degree of risk, but not less than once per year. Renewal is the PI’s responsibility, but as a reminder, you will receive notices at least 60 days and 30 days prior to the next review. Please note the continuing review date for your study.

Any modification of this research project must be submitted to the IRB for review and approval, prior to implementation. Modifications include but are not limited to: changing the protocol or study procedures, changing investigators or sponsors (funding sources), including additional key personnel, changing the Informed Consent Document, an increase in the total number of subjects anticipated, or adding new materials (e.g., letters, advertisements, questionnaires). Any future correspondence should include the IRB identification number provided and the study title.

You must promptly report any of the following to the IRB: (1) all serious and/or unexpected adverse experiences involving risks to subjects or others; and (2) any other unanticipated problems involving risks to subjects or others.

HSRO/ORC 9/02
Your research records may be audited at any time during or after the implementation of your study. Federal and University policy require that all research records be maintained for a period of three (3) years following the close of the research protocol. If the principal investigator terminates association with the University before that time, the signed informed consent documents should be given to the Departmental Executive Officer to be maintained.

Research investigators are expected comply with the University's Federal Wide Assurance, the Belmont Report, 45 CFR 46 and other applicable regulations prior to conducting the research. These documents are on the Human Subjects Research Office website or are available by calling (515) 294-4566.

Upon completion of the project, a Project Closure Form will need to be submitted to the Human Subjects Research Office to officially close the project.
October 24, 2003

Dr. Brian Hand
N 157 Lagomarcino
ISU
Ames, IA 50011

RE: Research - SWH Partnership

Dear Dr. Hand:

I am writing to notify you that your request to conduct research in the Ames Community Schools entitled SWH Partnership has been approved. The teachers have told us that they are looking forward to working with you on the project. If, in the course of your research effort, you determine that changes need to be made in our agreed upon procedures, please submit your proposed changes to me for approval before proceeding. I look forward to reading your summary report of research results, due no later than six months after completion of data collection. Please submit this summary to me at the Curriculum and Instruction Offices at 415 Stanton, Ames, IA 50010.

Sincerely,

[Signature]

Tony VanderZyl, Ph.D.
Coordinator of Program Evaluation and Data Analysis
Dear Students,

We are conducting research to determine how different writing tasks can improve the learning of scientific concepts. Dr. Brian Hand from The Center for Excellence in Science and Mathematics Education at Iowa State University is leading the research, while your student's science teacher and the school administration are willing to be a part of this project.

Last school year we conducted similar research that aimed to determine the effectiveness of different writing models in relation to science learning in a seventh grade Biology class and in freshmen Chemistry class. We found a significant improvement in understanding scientific concepts when using a particular writing format that goes beyond the typical laboratory and summary reports. Also we found that the increase in understanding strongly depends on teaching practices.

This year we will replicate this study in a larger scale including different grades and disciplines across different school districts in Iowa. The current study focuses on writing tasks, teaching practices, and the ability to communicate scientific concepts according to the goals indicated by the National Standards for Science Education. The science content covered during the current research is indicated by your student's science teacher, and is the same unit for all students regardless of the writing approach. We will be asking students to write about science concepts developed during the unit. At the end of these writing tasks students will be asked to communicate the learned scientific concepts in different writing styles, and to complete a survey regarding the writing tasks.

In order to assess teaching practices and their influence in the effectiveness of writing to learn, we would like to videotape and observe 3 sessions of your chemistry teacher. The observations and taping will be done in a way that will not disrupt the classroom. However, you may at times appear on tape, yet this would be used for analysis only. The ultimate outcome of this project is to improve the implementation of different writing tasks for achieving a high level of scientific literacy. The results of this research will be immediately incorporated in classroom, in educational programs for improving the preparation of teachers at Iowa State University and throughout the country.

In order to conduct this research we need permission for the following items:
1. To participate in this study
2. To use all data received from the study including participation in a survey after completion of the writing tasks.
3. To be included in the videotape.

Data will be collected from pre and post-tests, and text analysis of the written laboratory reports and a unit summary written piece. Finally, we will conduct a survey focused on students' thoughts concerning the writing process. All information collected will be held in the strictest of confidence by the teacher and the researchers. Only student I.D. numbers will be used in identification of student information. Your participation in this project is voluntary and you may decline your permission at any time. If you do not want to
be included, data will be eliminated from analysis but you will still be required to complete all the unit assignments.

We appreciate your support in helping to better construct future teaching approaches. We need your permission to participate in this project. We ask that you please read and sign the two permission forms if you do not want to be involved, and return them to the science teacher. If at any time you have questions regarding this project, please do not hesitate to contact us.

Sincerely,

Brian Hand, Professor  
Center For Excellence in Science & Mathematics Education  
N157 Lagomarcino Hall  
Phone: (515) 294-004  
E-mail: bhand@iastate.edu

Dr. Irene Grimberg  
Center For Excellence in Science & Mathematics Education  
N005 Lagomarcino Hall  
Phone: (515) 294-6167  
E-mail: grimberg@iastate.edu
Dear Parents,

We are conducting research to determine how different writing tasks can improve the learning of scientific concepts. Dr. Brian Hand from The Center for Excellence in Science and Mathematics Education at Iowa State University is leading the research, while your student’s science teacher and the school administration are willing to be a part of this project.

Last school year we conducted similar research that aimed to determine the effectiveness of different writing models in relation to science learning in a seventh grade Biology class and in freshmen Chemistry class. We found a significant improvement in understanding scientific concepts when using a particular writing format that goes beyond the typical laboratory and summary reports. Also we found that the increase in understanding strongly depends on teaching practices.

This year we will replicate this study in a larger scale including different grades and disciplines across different school districts in Iowa. The current study focuses on writing tasks, teaching practices, and the ability to communicate scientific concepts according to the goals indicated by the National Standards for Science Education. The science content covered during the current research is indicated by your student’s science teacher and is the same unit for all students regardless of the writing approach. We will be asking students to write about science concepts developed during the unit. At the end of these writing tasks, students will be asked to communicate the learned scientific concepts in different writing styles and to complete a survey regarding the writing tasks.

In order to assess teaching practices and their influence in the effectiveness of writing to learn, we would like to videotape your student’s science teacher 3 times this year each session lasting most of the class period. The observations and taping will be in a videoconference room and done in a way that will not disrupt the classroom. However, in videotaping your student’s science teacher, students in the class may at times appear on tape. The clips of your student’s science teacher will be used only in our study and will not be published in any way. The ultimate outcome of this project is to improve the implementation of different writing tasks for achieving a high level of scientific literacy. The results of this research will be immediately incorporated in your student classroom, in educational programs for improving the preparation of teachers at Iowa State University and throughout the country.

In order to conduct this research we need permission for the following items:
1. To allow your student to participate in this study
2. To use all data received from the study including participation in a survey after completion of the writing tasks.
3. To allow your student to be included in the videotape.

Data will be collected from pre and post-tests, and text analysis of the written laboratory reports and a unit summary written piece. Finally, we will conduct a survey focused on students’ thoughts concerning the writing process. All information collected will be held in
the strictest of confidence by the teacher and the researchers. Only student I.D. numbers will be used in identification of student information. At no time will teachers’ names or personal information be used in the collection, analysis or publication of the results. Your participation in this project is voluntary and you may decline your permission at any time. If you or your student does not want to be included, data will be eliminated from analysis but the student will still be required to complete all assignments. We appreciate your support in helping to better construct future teaching approaches, which are a part of the learning experiences for all students in the class. We need your permission and the permission of students 14 or older to participate in this project.

Please read and sign the permissions and retain the second copy for your record.

If at any time you have questions regarding this project, please do not hesitate to contact us.

Sincerely,

Brian Hand, Professor
Center For Excellence in Science & Mathematics Education
N157 Lagomarcino Hall
Phone: (515) 294-004
E-mail: bhand@iastate.edu

Dr. Irene Grimberg
Center For Excellence in Science & Mathematics Education
N005 Lagomarcino Hall
Phone: (515) 294-6167
E-mail: grimberg@iastate.edu
PERMISSION FOR DATA RELEASE
(Return to the teacher)

I give permission for ______________________________________
I Do Not give permission for ______________________________________

to take part in the above mentioned research and to release all data collected on my student
during the research process to the principal researchers.

Student Signature ________________ Parent Signature ________________

Date __________________________

PERMISSION FOR VIDEO TAPE
(Return to the teacher)

I give permission for ______________________________________
I Do Not give permission for ______________________________________

to take part in the above mentioned research and to be videotaped during the research process
to the principal researchers.

Student Signature ________________ Parent Signature ________________

Date __________________________
PERMISSION FOR DATA RELEASE  
(Keep as record)

I give permission for _______________________________________
I Do Not give permission for _______________________________________

to take part in the above mentioned research and to release all data collected on my student
during the research process to the principal researchers.

Student Signature ________________  Parent Signature ________________
Date ________________________

Contact Information

Dr. Brian Hand (bhand@iastate.edu)  Dr. Irene Grimberg (grimberg@iastate.edu)
Office: (515) 294-0033  Office: (515) 294-6167

PERMISSION FOR VIDEO TAPE  
(Keep as record)

I give permission for _______________________________________
I Do Not give permission for _______________________________________

to take part in the above mentioned research and to be videotaped during the research process
to the principal researchers.

Student Signature ________________  Parent Signature ________________
Date ________________________

Contact Information

Dr. Brian Hand (bhand@iastate.edu)  Dr. Irene Grimberg (grimberg@iastate.edu)
Office: (515) 294-0033  Office: (515) 294-6167