Using the science writing heuristic approach as a tool for assessing and promoting students' conceptual understanding and perceptions in the general chemistry laboratory

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Using the science writing heuristic approach as a tool for assessing and promoting students’ conceptual understanding and perceptions in the general chemistry laboratory

by

Elham Ghazi Mohammad

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, Co-Major Professor
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Iowa State University
Ames, Iowa
2007
DEDICATION

To my husband, Dr. Abdulilah Dawoud, for all his continuous support, motivation, patient, and encouragement. To my kids, Abdulqader, and Abdulhadi for their love and inspiration.
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ABSTRACT

This thesis reports on a study that examined the impact of implementing SWH (inquiry-based approach) in a general chemistry lab on non-science-major students’ understanding of chemistry concepts and students’ perceptions toward writing in science and implementing SWH. This study was conducted in a large university in the Midwest of the United States in a college freshman chemistry laboratory for non-science-major students. The research framework is presented including the following: the qualitative research design with the observation as data collection method for this design and the criteria for teacher level of implementation and the ranking mechanism; and the quantitative research design with data collection and analysis methods including pre- and post-conceptual exams, lecture question, open-ended surveys. This research was based on a quasi-experimental mixed-method design a focus on student performance on higher order conceptual questions, and open-ended survey at the end of semester about their perception toward writing to learn ad implementing SWH. Results from the qualitative and quantitative component indicated that implementing SWH approach has notably enhanced both male and female conceptual understanding and perception toward chemistry and implementing SWH. It is known that there is gender gap in science, where female have lower perception and self confident toward science. Interestingly, my findings have showed that implementing SWH helped closing the gap between male and female who started the semester with a statistically significant lower level of conceptual understanding of chemistry concepts among females than males.
CHAPTER ONE

Introduction

General Overview

Chemistry is broadly perceived to be a difficult subject (Markow & Lonning, 1998); where girls do not achieve as well as boys in science classrooms (Matyas, 1985). In fact, students’ prior knowledge determines how students learn new scientific knowledge and plays a crucial role in consequent learning (Arnaudin & Mintez, 1985; Boujaoude, 1991; Driver & Oldham, 1986; Tsai, 1996); whereas students’ misconceptions influence how they learn new scientific knowledge and often turn out to be an obstacle in acquiring the accurate body of knowledge (Özmen, 2004). While the cookbook (traditional) lab of general chemistry laboratory has been censure progressively more as an “unrealistic portrayal of chemical experimentation”, the students in this kind of lab complete their experiment with little perceptions, or investment of thought. As a result, during the last decade, several educators have emphasized the importance of using writing to enhance science learning (Keys, 1999; 2000; Prain & Hand, 1996; Sutton, 1993; Yore, Bisanz, & Hand, 2003).

The National Science Education Standard (1996) states that “learning science is an inquiry-based process,” and Keys et al. (1999) have emphasized that students need experiences with a variety of writing genres to communicate ideas. The classroom climate plays a significant role in both students’ science attainment and satisfaction with learning in science (Nolen, 2003). Writing is a human activity that individuals have been using for very long time as a medium to communicate. Hence, they have a special
characteristic that enables them to represent and translate interactions with environment, which includes feelings, thoughts, impressions, and actions, by using verbal language (Keys, 1999).

In science, scientists use writing to explain the natural world and phenomenon surround us and to articulate their understanding of science by writing (Keys, Hand, Prain, & Collins, 1999). Therefore, writing is primary tool for student learning (Bean, 1996; Howard & Jamieson, 1995; McLeod & Miraglia, 2001), in which students demonstrate what they know (Bereiter & Scardamalia, 1987), become better communicators, construct new knowledge and think critically (Klein, 1999), and express their understanding of science (Keys, Hand, Prain, & Collins, 1999). Accordingly, teachers have discovered that the use of writing has changed their classroom environment for the positive (Herrington, 1981; Howard & Jamieson, 1995). Most studies of science learning environments have used correlation analyses of the relationships between students’ perceptions of different aspects of their learning environment and students’ performance. Positive correlations between science attitude and science achievement have been found (Schibeci & Riley, 1986; Simpson & Oliver, 1990).

Nolen (2003) indicated that shared attitudes of the classroom climate play a significant role in both students’ science attainment and satisfaction with learning in science, as was demonstrated in a study based on high school students’ perceptions of their science learning and their motivation, learning strategies, and achievement. Yore et al. (2003) found that for elementary schools students, attitudes toward science learning were mostly composed of: attitudes towards school science, science careers, nature of science, and self confidence.
Writing is one of the most important teaching interventions that could help students become better communicators and enables them to construct new knowledge and think critically (Klein, 1999). The purpose beyond writing is to communicate information with others (Galbraith & Rijlaarsdam, 1999; Hand & Prain, 2006). Whereas there has been strong advocacy of the value of writing for learning in science, the role of student planning in this approach and the relationships between planning, writing, and learning have been under researched (Hand, Hohenshell, & Prain, 2004). Prain and Hand (1999) suggested that the implementation of writing-for-learning strategies have various beneficial effects on changing students’ perceptions about learning science, enhancing females students’ understanding and perceptions toward science, and affecting the achievement gap between males and females (Hohenshell, 2004; Poock, Burke, Greenbowe, & Hand, 2004).

Strenski (1984) demonstrated writing as a proficiency activity, where the writing is a path to learning. Consequently, science educators have been calling for the insertion of inquiry-based approaches in science classrooms as a change for science instruction. Consequently, students would construct their own science conceptions, through interacting with other students, materials, and the teacher in the classroom context under the teacher’s guidance. Hand and Keys (1999) developed the Science Writing Heuristic (SWH) as a tool to promote and scaffold scientific argumentation within science classrooms.

The SWH is constituted by a teacher and a student component that emphasize a student-centered and a writing-to-learn perspective. In particular, the students are prompt to formulate their own research questions to describe the experimental procedure, to
report their experimental findings, to set their claims and evidence, to analyze or negotiate other informational sources, and to reflect on their own ideas about the scientific topics. As I discussed before, these tasks not only require a rich range of writing forms, but also a critical involvement of students through the construction of individual meaning (as in setting claims and evidence), and argumentation with their peers in order to reach a consensus science understanding. For instance, Merritt, Schneider, and Darlington (1993) argued that students learning of chemistry would improved while they effectively involve in planning of the experimental approach because they need to understand what they were doing before, during, and after the lab; they have a sense of ownership while they are designing their own experiment; and they need to master the principles of the experiment in order to explain what they are doing to one another while they are working together in the chemistry lab.

The role of writing in science learning has a dual character; it is a tool through which students demonstrate what they know (Bereiter & Scardamalia, 1987). Writing can be organized as a sequence of tasks that address these strategies; an example of such approach is the Science Writing Heuristic (SWH; Hand & Keys, 1999) for laboratory activities. Hand and Keys (1999), in an attempt to develop a rich teaching/learning approach using these ideas, constructed the SWH, which they believe to be an inquiry-based approach that links writing, reading, and science laboratory activities. The structure 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 (Table 1).

The student template 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” (Omar, 2004, p. 34).

The SWH template 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 differentiate scientific meaning from reasoning (Omar, 2004). A comparison of the components of the SWH student template to the traditional laboratory report template demonstrates the differences between the two templates (Akkus, Gunel, & Hand, 2007) (Table 2)

Table 1: Features of Students' SWH lab report.

<table>
<thead>
<tr>
<th>• <strong>Beginning questions or ideas</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>What are my questions about this experiment?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>• <strong>Tests and Procedures</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>What will I do to answer my questions?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>• <strong>Observations</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>What did I see when I completed my tests and procedure?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>• <strong>Claims</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>What can I claim?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>• <strong>Evidence</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>What evidence do I have to support my claim? How do I know?</td>
</tr>
<tr>
<td>Why am I making these claims?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>• <strong>Reflection/ Reading</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>How are my ideas compared with others?</td>
</tr>
<tr>
<td>How have my ideas been changed?</td>
</tr>
<tr>
<td>How is it compared to the textbook’s Lecture?</td>
</tr>
</tbody>
</table>
Table 2. Comparison of the SWH format to traditional format

<table>
<thead>
<tr>
<th>SWH Format</th>
<th>Traditional Format</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beginning questions</td>
<td>Title, purpose</td>
</tr>
<tr>
<td>Test and procedure</td>
<td>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>Equations, calculations, graphs</td>
</tr>
<tr>
<td>Reflection/ Reading:</td>
<td>No Equivalent</td>
</tr>
</tbody>
</table>

**Purpose**

The purpose of my research is to investigate what impact, if any, implementing the SWH approach in a general chemistry lab has on student understanding of specific heat, solution calorimetry, and designing an experiment and to assess the students’ ability and perceptions toward writing in science and implementing SWH while they are studying in a general chemistry lab, according to teacher level of implementing SWH, gender differences, and student achievement.

**Research Questions**

The theoretical literature review described above stimulated the following central question of my research:

“Will implementing an inquiry approach (SWH template or approach) help freshman chemistry students better understand concepts and improve their perceptions of chemistry?”
To address this overarching question, the following questions guided my research:

1) What impact does the level of teacher implementation of the SWH (high or low) have on students’ conceptual understanding of heat transfer, solution calorimetry, and designing an experiment?

2) What impact does implementation of the SWH have on gender differences in students’ score of heat transfer, solution calorimetry, and their achievement in designing an experiment?

3) Does the two- and three-way interactions between teacher implementation level (high or low), students’ gender, and/or students’ achievement (bottom half and top half) have an impact on student scores of heat transfer, solution calorimetry, and their achievement in designing an experiment?

4) What impact does the implementation level of the SWH have on students’ perceptions about implementing SWH in the general chemistry lab including their perceptions about having control of lab activity, changing their ideas, and the value of the reflection component of the SWH template?

5) What impact does implementation of the SWH have on students’ perception about implementing SWH in the general chemistry lab including their perception of having control of the lab activity, changing their ideas, and the reflection component of the SWH template according to students’ gender?

6) What impact does implementation of the SWH have on students’ perceptions about implementing SWH in the general chemistry lab including their perception of having control of the lab activity, changing their ideas, and the reflection
component of the SWH template according to students’ achievement (top half and bottom half)?

7) What impact does the two- and three-way interactions between teacher implementation level (high or low), student gender, student achievement (bottom half and top half) have on students’ perception about implementing SWH in the general chemistry lab including their perceptions about having control of lab activity, changing their ideas, and the value of the reflection component of the SWH template?

Outline of the Dissertation

Chapter 1: Introduction

The research proposal is used as an introduction chapter.

Chapter 2: Literature Review

In the literature review, appropriate readings that lead this research are analyzed.

I- Students’ prior knowledge
   a- Student misconceptions in chemistry
   b- Students misconceptions in thermodynamics
   c- Students’ perceptions toward chemistry
   d- What makes chemistry difficult?

II- Gender Gap in Science

III- Writing in science
   a. Writing Across the Curriculum (WAC)
b. Writing as a learning tool

c. Writing to learn in science

d. Science Writing Heuristic

Chapter 3: Method

I. Research Setting and Participants

This study was conducted in a general chemistry lab for non-science-major students, and the general chemistry lab was taught at a large university in the Midwest of the United States. Most of undergraduate students enrolled in the general chemistry lab and course at the same time are involved in the study, and six teaching assistants (TAs) taught 9 lab sections, with some TAs teaching two labs.

II. Research Framework

In this study, a mixed (qualitative and quantitative) approach to research was applied. Fraser and Tobin (1992) emphasized that gathering and analyzing both quantitative and qualitative data will add to the richness of the study.

III. Qualitative Research Design

The qualitative measures involved observations of TAs and students in the laboratory. The practice of each teacher was ranked and used to inform the implementation level. Each teacher was ranked based on his or her level of implementation.

IV. Quantitative Research Design:

The purpose of the quantitative component was to answer all research questions. Therefore, a mixed-method, quasi-experimental, pre-post connectional exam design with two groups was used. In addition, data was collected using an open ended-survey
regarding freshman non-science major students perceptions of implementing SWH in a general chemistry lab.

Chapter 4: Results (quantitative results)

This chapter focused on the results of the quantitative component which aim to answer all research questions and led me to achieve the purpose of study. In this chapter the quantitative results were obtained according to teacher level of implementing SWH, gender differences, and student achievement based upon students’ results on the pre- and post- conceptual exam on the concepts of specific heat, solution calorimetry, and of designing the experiment; also based upon student response in the survey.

Chapter 5: Discussion, Implications, and Limitations

The last chapter of the dissertation presents discussion, implications, and limitations based on the qualitative, quantitative results, and their relation to current literature. The purpose of this chapter is to address the impact of implementing SWH (an inquiry-based approach) in a general chemistry lab on non-science-major students’ understanding of chemistry concepts and students’ perceptions toward writing in science and implementing SWH.
CHAPTER TWO

Literature Review

General Overview

This literature review examines the related literature to provide a theoretical framework for answering the research questions. This chapter is organized in sections. In the first part of the review, theory about students’ prior knowledge, students’ misconceptions in chemistry, students’ misconceptions in thermodynamics, students’ perceptions toward chemistry, and what makes chemistry difficult are the areas of interest examined in detail. The second part of the review focuses on the gender gap in science where males and females differ in achievement, attitude, motivation, and interest in science and chemistry. The reason for this gap is also examined. The last part of the review focuses on Writing Across the Curriculum (WAC), writing as a learning tool, writing to learn in science and the needs and calls for changing the way of teaching from traditional approaches and traditional format of the chemistry lab report to the SWH approach (inquiry approach) and SWH format of the chemistry lab. Later, the crucial role of the SWH approach in terms of enhancing the females’ understanding and perceptions toward science is highlighted.

Students’ Prior Knowledge

The knowledge stored in our brains consists of networks of concepts and these concepts are combined to form statements or propositions (Falk & Adelman, 2003). The important role played by prior knowledge and experience is widely appreciated and
discussed, and students’ prior knowledge has great influence on learning new knowledge (Thompson & Zamboanga, 2003; Yenilmez, Sungur & Tekkaya, 2006) given that the new knowledge is constructed upon what students already know (Ausubel, 1968). Consequently, individuals with restricted prior knowledge understand and remember less than those with better prior knowledge (Glaser, 1984) and use strategies less effectively than those with higher prior knowledge (Alexander & Judy, 1988). Therefore, Ausubel (1968) argued that we, as teachers, need to determine what the learner already knows and then teach the learner accordingly.

Educators agree that learners as individuals construct their own new understanding based on the interaction between what they already know and the new ideas which they experience to make sense of their instructional science experiences (Driver & Easley, 1978,). Indeed, constructivist theory argues that all new learning builds on preexisting understanding (McCormick & Pressley, 1997). Constructivism, as a learning theory, accentuates the role of the learner’s existing conceptual structure in making sense of the new learning experience (Omar, 2004).

Thus, educators assert that constructivism is an epistemological descriptive theory of learning, which describes the way individuals should learn (Richardson, 1997). According to Strike (1987), the basic assumption of constructivism learning is that learners have to carry out learning experiences themselves. In the late 1970s, educators accepted the idea of the active role of the learners in defining knowledge with respect to their experiences, whether in isolated settings where no interaction with others occurs or in social contexts where interaction with others occurs (Von Glasersfeld, 1988). For instance, Farenga and Joyce (1999) stated the following:
Science is a construct in the world that is constantly presented to the child. The child is a natural scientist asking questions to seek answers to his or her natural world. The child’s attitude toward science may be affected by the manner in which science is converted to an object and the reality that is created by the child to interpret that object. The child must convert science into an object that he or she then manipulates to gain insight. (p. 58)

Furthermore, Özmen (2004) argued that learning is a cumulative process and each new piece of knowledge about a topic is added to what students already know. In spite of the learning perspective, the process of knowledge construction results in the development of a learner’s conceptual structure where new knowledge is created. Posner et al (1982) commented on the role of conceptual structures in knowledge generation:

The nature of these concepts 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)

**Student Misconceptions in Chemistry**

Students bring many misconceptions about scientific phenomena to their lessons, misconception which can obstruct the students’ learning of accurate scientific concepts (Driver & Easley, 1978; Driver & Erickson, 1983; Posner et al., 1982). For instance, the term *misconceptions* refers to the ideas that students have about natural phenomena which are incompatible with scientific conceptions (Chambers & Andre, 1997). These misconceptions may occur as a result of the variety of interactions made by students, like
interaction with teachers and the community, as a result of individual experiences, or as a result of exposure to media (Gilbert et al., 1982; Griffiths & Preston, 1992). Also, students’ inability to employ formal operations, a lack of prior knowledge, and a lack of related concepts in long-term memory are other fundamental causes for misconceptions in science (Tsaparlis, 1997).

The misconceptions of the individual student, according to the constructivist theory of learning, are especially important because knowledge is constructed exclusively by each individual learner and learners actively construct knowledge to make sense of the world, interpreting new information in terms of existing cognitive structures (Taber & Watts, 1997). The particular knowledge that is constructed by an individual student will be influenced by the student’s prior knowledge and experience and the social background in which learning takes place (Grayson et al., 2001; Von Glasersfeld, 1992). When the student is faced with a new idea, he or she can treat it in a number of ways (Ausubel & Robinson, 1969). The student can place it in a section next to his existing body of knowledge and not try to incorporate it. Another possibility is that he or she can attempt to connect the new knowledge to the existing knowledge, and the student may make incorrect connections (Ausubel, 1968). A third option is that a student integrates his or her new knowledge correctly into present knowledge and applies clear understanding to the new concepts (Johnstone et al., 1977).

Misconceptions are defined as student preconceptions that are different and incompatible with accepted scientific consensus, and these preconceptions are unable to explain scientific phenomena (Bodner, 1986; Cho, Kahle, & Nordland, 1985). Some student misconceptions appear reasonable to the student and are harmonious with his or
her understanding of the world, and these student misconceptions are very resistant to change (Herron, 1990). Several researchers have implicated instructor comments or textbooks as sources of some student misconceptions (Garnett & Treagust, 1990, 1992; Sanger & Greenbowe, 1999).

Students’ prior knowledge determines how students learn new scientific knowledge and plays a crucial role in consequent learning (Arnaudin & Mintez, 1985; Boujaoude, 1991; Driver & Oldham, 1986; Tsai, 1996). Students’ difficulties in science happen because students’ conceptions before teaching are not taken into account, and, as a result, effectual communication between teachers and students does not take place (Hunt & Minstrell, 1996).

Since students’ misconceptions in science are a major concern to science educators, the detection and understanding of students’ misconceptions in chemistry have been the goal of recent studies (Özmen, 2004; Peterson & Treagust, 1989). Most studies have been conducted on the following concepts: elements, compounds, and mixtures (Ayas & Demirbas, 1997; Papageorgiou & Sakka, 2000); chemical bonding (Özmen, 2004; Peterson et al., 1986; Taber, 1994); chemical equilibrium (Bergquist & Heikkinen, 1990; Maskill & Cachapuz, 1989; Niaz, 2001); chemical reactions (Andersson, 1990; Hesse & Anderson, 1992); atoms and molecules (Ben-Zvi et al., 1986; Griffiths & Preston, 1992; Harrison & Treagust, 2000; Lee et al., 1993); acids and bases (Bradley & Mosimege, 1998; Hand & Treagust, 1991); and the mole concept (Furio et al., 2000; Gorin, 1994; Schmidt, 1994). Students have misconceptions in these areas because of the abstract nature of chemical concepts and the difficulty of the language of chemistry (Ayas & Demirbas, 1997).
These misconceptions are resistant to change over time, despite increased chemistry education. For example, students may pass from grade to grade without completely grasping the fundamental concepts of bonding and instead develop misconceptions for a variety of reasons. For example, in classroom teaching, teachers generally use ball and stick models to symbolize chemical bonds. But, using ball and glue models to model ionic nets may create misconceptions about bonding because learners’ mistake sticks for individual chemical bonds (Butts & Smith, 1987).

A significant amount of research has indicated that the process of knowledge construction engages the substitute of the conceptual framework. But for several concepts, such as acids and bases, students have trouble replacing or rearranging their early perceptions of the concepts. Instead, the abstract concepts provide increased opportunity for the expansion of misconceptions (Özmen, 2004). Indeed, Khalid (2003) stated that even after learning the accurate concepts in the classrooms, the students have such strong misconceptions that their preconceptions do not change. Instead, students try to understand the newly acquired knowledge using their incorrect preconceptions.

**Students Misconceptions in Thermodynamics**

Students’ understanding of heat and thermal phenomena has been the subject of major exploration in the chemical education literature (Ben-Zvi, 1999; Harrison et al., 1999; Johnstone et al., 1977; Lewis & Linn, 1994). A few studies have focused on thermodynamics in the university-level (Rozier & Viennot 1991, ), and some studies into student learning of chemical thermodynamics at the university level (Beall, 1994; Thomas & Schwenz, 1998; Van Roon et al., 1994). For example. Jasien and Oberem (2002) determined that the knowledge of science students and pre-service teachers
investigated in their study was limited in the areas of thermal equilibrium, heat capacity, and specific heat. This was among even practicing physical science teachers at the middle- and high-school levels.

Many students have misguided views of heat and temperature (Erickson & Tiberghien, 1985) including the beliefs that heat and temperature are the same thing that temperature of an object is the amount of heat it possesses, and that heat is substantive and can be possessed, lost, or gained by an object. The difficulties in understanding the difference between heat and temperature that are demonstrated by school students continue in these college freshmen (Beall, 1994; Erickson & Tiberghien, 1985). Along the same lines, Kesidou and Duit (1993) discussed the common student misunderstanding between the terms of heat and temperature. Not only must students differentiate these concepts, they must learn to resolve each in an interactive way so that once they distinguish how heat and temperature differ, they can then understand how they are related to each other. Right now, “a number of serious and widespread thermochemical misconceptions are developed among college chemistry students, even those who are successful in solving algorithmic calorimetry problems” (Greenbow & Meltzer, 2003, p. 796). Several studies have focused on students’ difficulties in understanding and distinguishing between exothermic and endothermic reactions (De Vos & Verdonk, 1986; Novick & Nussbaum, 1978), while, calorimetry actually has received few thoughts from researchers in chemical education (Ebenezer & Fraser, 2001; Greenbow & Meltzer, 2003).
Students’ Perceptions Toward Chemistry

Getting students to like science, one of the main obstacles educators must overcome, is correlated to students’ attitudes, which, in turn, is related to students’ interest, motivation, and achievement (Glick, 1970; Harty, Beall, & Scharmann, 1985). In fact, students’ perceptions about science appear to be shaped by teachers, learning environment, self-concept, peers, and parental influence (Glick, 1970; Haladyna, Olsen, & Shaughnessy, 1983). Those attitudes toward science may have an effect on students’ motivation, interest, and achievement in the sciences (Rennie & Punch, 1991; Shrigley, 1990). Further, positive correlations between science achievement and science attitude have been found (Schibeci & Riley, 1986; Simpson & Oliver, 1990), and other studies have provided correlational analyses of the relationship between students’ perceptions of various aspects of their environment and their grades and attitude toward science (Fraser, 1994, 1998).

Ames and Archer (1988) outlined that students were more likely to report using efficient strategies during challenging tasks, expending increased effort, and experiencing a positive affect toward school when they perceived their classrooms as mastery oriented; but, when students perceived their classrooms as more focused on ability contrasts and avoiding mistakes, they tended to characterize poor performance as a deficiency in ability. Nolen (2003) established that students’ perceptions of their science learning, motivation, and achievement, combined with attitudes about the classroom climate, play a significant role in both students’ science achievement and accomplishment in learning science. Considering students’ perceptions and attitudes is important to opening science learning to all. Wallace, Hand, and Prain (2004, p. 3) stated that “science is for all students, not
just those who are scientifically talented. Students at all stages of development should have opportunities for rich experiences in science, including various forms of scientific writing.”

Encouraging students to think and to apply the chemistry concepts they learn has been one of the major purposes for most chemistry instructors (Cooper, 1993), but the major challenge facing teachers is the diversity of student backgrounds, abilities, and interests, particularly in introductory courses (Kovac & Sherwood, 1999). Okebukola (1986) acknowledged some factors related to teacher, student, and laboratory environment that affect students' attitudes toward chemistry. He found that the attitude of the student toward chemistry as a subject is the most important factor of the student attitude toward the laboratory. The second important factor was the students’ contribution in laboratory activities, in which students' involvement in "hands-on" activities, may lead to improved skills, which promote a more positive attitude toward science (Okebukola, 1986; Druva & Anderson, 1983), whereas “the location of the school and the experience of the chemistry teacher were not significantly correlated with students' attitudes toward the chemistry laboratory” (Okebukola, 1986, p. 532). Okebukola also suggested the following:

A greater degree of participation in laboratory work may produce more positive attitudes toward the laboratory. While laboratory equipment and materials may not be available in sufficient quantities, being resourceful is worthwhile. Our students should be more motivated to participate in and perform better in the laboratory. (p. 532)

One way to integrate interactivity into the science laboratory is the use of writing,
which is one of “the most powerful techniques,” and perhaps the oldest, that can accommodate the diversity of the students’ background, interests, and skills and help the chemistry instructors facilitate active learning and critical thinking (Hanson & Wolfskill, 1998; Kovac & Sherwood, 1999). Indeed, Prain and Hand (1999) suggested that the implementation of writing-for-learning strategies has various beneficial effects on students’ perceptions about learning science.

**What Makes Chemistry Difficult?**

Chemistry is considered to be a difficult school subject (Markow & Lonning, 1998) by students (even among high achieving students), teachers, educators, and researchers (Özmen, 2004). Often, students’ prior knowledge of chemistry is not what is predictable or preferred by chemistry educators (Kirkwood & Symington, 1996; Noh & Scharmann, 1997). In fact, according to Hewson and Hewson (1983), the significant source of learning difficulties experienced by chemistry students was due to their prior knowledge. However, teachers are more likely than students to say that chemistry is simply difficult, and they believe that chemistry is difficult because teachers are more aware of what they and their students do not know (Sözbilir, 2004). On the other hand, “student disinterest and feeling of irrelevance of the subject matter, student perception of lack of involvement in a large lecture course: and the student tendency to look for equations to memorize rather than concepts to learn” are some “well-recognized problems” linked to the teaching of general chemistry (Beall, 1991).

This difficulty in chemistry might be due to the abstraction of the nature of chemistry topics (Ben-Zvi et al., 1988), the complexity of language used with different meanings (Bergquist & Heikkinen, 1990), and student perceptions toward the context of
chemistry courses, all of which influence their learning. Carter and Brickhouse (1989) argued that the different perceptions toward chemistry exist between students and teachers “because their experiences, knowledge, goals, needs, and motivations are different … we may begin to understand student difficulties in chemistry if we understand the ways in which their perceptions of the context of our chemistry courses differ from our perceptions.” (p. 223). Furthermore, difficulty in chemistry may be caused by students’ low ability in applying chemistry knowledge to solve chemistry problems (Bunce, Gable, & Samuel, 1991; Herron, 1990; Yarroch, 1985), students’ inability to construct their own chemistry meaning (instead, they learn by rote), and instruction that fails to help students distinguish the concepts and relationships required to understand the chemistry subject matter (as a result, chemistry remains “conceptually opaque” to students) (Pendley, Bretz, & Novak, 1994). In addition, chemistry is viewed as difficult because “the faculty see students as too dependent on algorithms and the students indicate that chemistry has too many rules (likely algorithms) for which the exceptions are frustratingly numerous” (Hand, Yang, & Bruxvoort, 2007, p. 127).

Once in a while when the prior knowledge is inaccurate, incomplete, or inappropriate, stemming from everyday experience or from what students have learned previously, then learning new information will be difficult (Alexander & Judy, 1988; Chinn & Brewer, 1993; Dochy et al., 1999). Furthermore, students’ misconceptions become the most important anxiety amongst researchers in science education because these misconceptions play an important role in the success of learning. Misconceptions influence how students learn new scientific knowledge and often turn out to be an obstacle in acquiring the accurate body of knowledge (Ozmen, 2004).
Gender Gap in Science

Gender differences in science have received enormous consideration in science education research for the last two decades, where, male and female have been compared on variables such as achievement, attitude, motivation, and interest (Erickson & Erickson, 1984; Greenfield, 1997; Kahle, Parker, Rennie, & Riley, 1993; Keeves & Kotte, 1992; Morrell & Lederman, 1998; Simpson & Oliver, 1985; Yezierski & Birk, 2006).

In general, research has constantly showed that girls do not achieve as well as boys in the science classroom (Matyas, 1985). Consequently, females go to college with fewer science experiences and mathematical skills, which, in turn, lowers the science self-confidence among these female students (Kahle, 1985; Sells, 1973). Hanson (1996) pointed out that the gender gap appears much earlier in science than in mathematics, and fewer girls in college choose science as their major field of study.

Furthermore, males and females exhibit differences in the type of science they choose to experience (Baker, 1990; Farenga, 1995; Walberg, 1967); which bears out in achievement scores in chemistry and physics with regard to gender (Becker, 1989). Subjects such as mathematics, physics, and chemistry are considered masculine, while subjects such as biology, art, and language are professed as feminine (Farenga & Joyce, 1999). Young and Fraser (1994) highlighted the significant gender differences in biology achievement in favor of the boys, while Keeves and Kotte (1992) pointed out that female students are enrolled more in biology course with no achievement differences.

Additionally, Jones, Howe, and Rua (2000) argued that early experiences in science are crucial to robust understanding of scientific concepts; in fact, Yezierski and
Birk (2006) and Jones, Howe, and Rua (2000) emphasized that the gender gap tends to enlarge and favor males as students get older starting from middle school levels.

Moreover, Kotte (1992) reported that the sharpest increase in gender differences in attitudes occurs between the ages of 10 and 14 years, and girls’ attitudes toward science tend to turn down during this time and this turning down may continue through high school (Kahle & Lakes, 1983).

Based on the emphasis placed on the factors responsible for these gender differences, several researchers (Bazler & Simonis, 1991; Bianchini, 1993; Jones & Wheatley, 1989) have found that materials, such as textbooks and bulletin boards, used to teach science in schools can replicate and strengthen the instructional gender bias more with males than with females. Gender differences were more an attribute of a whole class than of group activities (Kahle & Meece, 1994). Moreover, males and females go into school science classrooms with different attitudes and, different past experiences and concerns (Johnston, 1984), and those differences can have an impact that extends through college and into the professional years. Thus far, Catsambis (1995) has found that females were less expected to look ahead to science class and to think science would be functional in their future, and females were more afraid to ask questions in science classes than their male classmates. Besides, females received less attention from teachers than males do in science classrooms, as they are called upon less frequently to answer questions and given less freedom to call out answers (Kahle & Lakes, 1983; Tobin, Kahle, & Fraser, 1990).

Johnston (1984) argues that the science classroom is fundamentally biased towards male students’ needs:
The science classroom and curriculum are designed to build on the foundation of interest, experiences, and attitudes that is present for one sex but not present for the other. Treating boys and girls identically in school can only accentuate rather than diminish the existing differences. (p. 22)

Teacher behavior affects boy and girls differently (Matyas, 1985). Girls receive less direct questions from their teacher than do boys, and girls are praised less frequently than boys for answering the question correctly. Thus, girls have less interaction with teachers than do boys (Brophy & Good, 1970). Alternatively, girls receive more criticism on their academic performance than of their classroom actions (Matyas, 1985), so a considerable reason for girls’ lack of self-possession and anticipation for success in academic settings might be a result of negative academic interactions with their teachers (Fennema & Sherman, 1977). Many researchers concur that the importance of the teacher in developing girls’ attitudes toward science cannot be exaggerated (Matyas, 1985), since female scientists reported that the support and encouragement of a high school teacher was the deciding reason in their choice of a career in science (Remick & Miller, 1978).

Writing in Science

Writing Across the Curriculum (WAC)

The Writing Across the Curriculum (WAC) movement gained currency in the late 1970s and became widely accepted in universities throughout the 1980s, as is illustrated in attempts by various colleges and universities to expand the scope of student writing beyond the limits of English departments. Knoblauch and Brannon (1983) stated:

Meanwhile, if students have frequent opportunities to learn by writing throughout
their curricula and across all levels of education from the primary grades to graduate school, the English department’s special concern for literacy is likely to be far better served than it is now … it will be easy enough for historians and biologists to show thinking, verbally acute human beings how to write in their professional modes, provided we teachers, collectively, have worked to develop thinking, verbally acute human beings in the first place. (pp. 473-474)

Initially, the WAC movement came in as a powerful force and remained strong. The movement has turned out two major perspectives, with the primary idea that the more students write the more they learn: writing to learn where writing is a primary tool in learning, and writing in the disciplines where students need to be able to write in all different areas (Kiser, 2006). Further, the WAC movement has defined the functional types of written language as transactional, poetic, and expressive (Britton, 1970; Britton, Burgess, Martin, McLeod, & Rosen, 1975).

Often students come to college unqualified to do the writing required of them. Some students lack basic writing skills and most of them do not arrive at college knowing how to write well (Kiser, 2006; Knoblauch & Brannon, 1983; Little, 2003). Kiser (2006) observed that “although writing continues to be important at “Walker College,” many of the current professors are not knowledgeable about using writing in ways other than assessment of student learning, as in research papers.” (p. 27). Further, Kiser, (2006) stated:

The writing-across-the-curriculum movement is a naturally to constructivist philosophies. With a strong emphasis on student-centered curriculum and process writing, early WAC advocates drew many ideas from constructivism, especially
social constructivism and the focus on language as a social construct. (pp. 28-29)

The importance of teaching and using of writing has shifted from its emotionless features towards a process of writing and making meaning through writing: “WAC has challenged teachers in every discipline to think more about the context and nature of student learning than they might within the traditional content-driven model of college teaching” (Parks & Goldblatt, 2000, p. 584).

**Writing as a Learning Tool**

“Writing represents a unique mode of learning—not merely valuable, not merely special, but unique” (Emig, 1977, p. 122). Actually, many researchers believe in the importance of writing as a primary tool for student learning and to help students think (Chaffee, 2002; Emig, 1977; Howard & Jamieson, 1995; Nilson, 1998). Emig (1977) concluded that “writing involves the fullest possible functioning of the brain” (p. 125), while Chaffee (2002) argued that, “writing, with its power to represent our thoughts, feelings, and experiences symbolically, is the most important tool our thinking process has. Used together, thinking and writing enable us to create and communicate meaning” (p. 4). Indeed, writing also helps us negotiate and master new information (Hairston, 1992) agrees. Not only do students learn material better when writing is involved, but, according to Nilson (1998), “the power of writing is that it forces students to actively think about the material” (p. 123). Good writing results from having something to write, writing it, and revising it (Zimmerman, 1977).

Many scholars have advocated the extensive use of writing for various reasons, one of which is that writing helps students think. First emphasized by Britton (1972, 1977) and Emig (1983), others have also concluded that writing is a primary tool for
student learning (Bean, 1996; Howard & Jamieson, 1995; McLeod & Miraglia, 2001). In fact, Emig (1983) concluded that “writing involves the fullest possible functioning of the brain” (p. 126). Chaffee (2002) writes, “Writing, with its power to represent our thoughts feelings, and experiences symbolically, is the most important tool our thinking process has, that, used together, thinking and writing enable us to create and communicate meaning” (p. 4). Not only do students learn material better when writing is involved, but, according to Nilson (1998), they “retain it longer” (p. 123). She believes “the power of writing is that it forces students to actively think about the material” (Nilson, 1998, p. 123). As a teaching tool for active learning, writing can play a tremendous role.

Light (2001) stated that students care intensely about writing and that they want help to progress in this area. Hence, students must become scientifically literate in order to make informed decisions on unified educational and scientific issues. Moreover, without scientific literacy, it is difficult to make informed decisions about these issues (Glynn & Muth, 1994). Holliday, Yore, and Alvermann (1994) argued that for the student to be scientifically literate, students must have the reading and the writing ability to communicate their thoughts to others and to evaluate the information presented to them. In addition, when students write about science topics, they can find out new ideas and explain their thinking (Holliday, 1992; Rivard, 1994), and they can identify their knowledge gaps and misconceptions and articulate their rational and emotional reactions to science phenomena (Glynn & Muth, 1994).

Not only does the use of writing in the classroom result in positive rewards for students, it also increases instructors’ satisfaction and effectiveness (Herrington, 1981; Howard & Jamieson, 1995), since teachers have discovered that the use of writing has
changed their classroom environment for the positive. Anson (2002) pointed out that faculty who use writing recognize “that students become more active learners, more thoughtful readers, and more engaged participants in class.” Moreover, Bean (1996) acknowledged that “professors who successfully integrate writing and critical thinking tasks into their courses often report a satisfying increase in their teaching pleasure: class discussions are richer, students are more fully engaged in their learning, and the quality of their performance improves” (p. 1).

When writing is used as a tool for learning and for classroom conversation, the emphasis is on writing as conversation, speculation, and problem solving. Writing used in this way enables writing to proceed in a way that actively engages all the participants in the development of knowledge (Young, 1997). Moreover, Knoblauch and Brannon (1983) clarified the important of writing to learn:

One way to facilitate students’ learning about a subject is to have them write, because learning and articulating are inseparable activities. Writing enables new knowledge because it involves precisely that active effort to state relationships which is at the heart of learning. (pp. 467-468)

Fellows (1994) expressed the value of students’ writing as a window for understanding knowledge changes, since students’ writing can illustrate how they are thinking and struggling with concepts. In order to facilitate students’ knowledge changes and to help students make sense of their own science, the classroom might help to connect the collaborative group with the students writing which serve as mechanism for inspiring the reflection and feedback (Fellows, 1994). In fact, Wallace stated:

When the students learn, they discover what it is they think, so that they come to
a better understanding of what they know and what remains a gap in their knowledge… Thus, metacognition is a form of learning that is produced by writing, while at the same time, it is a catalyst and, thus, part of the process for content learning”. (2004, p. 12)

**Writing to Learn in Science**

There is much concern about the science literacy of the students who graduate from our high schools (American Association for the Advancement of Science {AAAS}, 1993; Hanson, 1988). For instance, Allan (1987) stated that the traditional view about integrated writing taking place in English courses or in few subjects, like in the form of reports or research essay, is not precise anymore; instead, there are diverse approaches to writing that are naturally integrated for different types of purposes, in which one type of writing supplements learning in the other mode.

Increasingly, using writing in science as a learning tool has been steadily growing since the 1980s. The tool, which was known as writing across the curriculum, incorporates both informal and formal writing into all science disciplines; hence, it deals with any types of writing that can help learners construct meaning (Connally & Villardi, 1989). Besides, Carlisle and Kinsinger (1977) argued that the ability to communicate clearly and efficiently in science is critical.

Even if writing about science in the classroom would not increase science understanding, it would, as a minimum, increase learners’ scientific writing performance. Additionally, Alamargot and Chanquoy (2001) discussed the importance of revision in writing activities:
To realize these operations [related to brain activities] it is necessary, at least, (1) to choose the “appropriate words” for each idea, (2) to use very strict syntactic, grammatical and orthographic rules, (3) to use correct punctuation and correction marks, in order to translate, in terms of linguistic relations, the semantic relationships linking these ideas. These mental activities are still not sufficient to elaborate a text. A satisfactory text is only very rarely produced during the first trial. It is often the result of an important numbers of drafts, corrections, scratches, additions, and so on. (p. 1)

Bereiter and Scardamalia (1987) created two types of writing models, “knowledge telling” and “knowledge transforming,” according to the writer’s level of experience. They reported that the difference between novice and expert writers is similar to the difference between knowledge telling and knowledge transforming. To differentiate the cognitive process attributed to each, knowledge telling reflects simply the translation (verbalizing) of thoughts directly into words. This model relies on the existing knowledge structures of the learner. In other words, the learner only retrieves ideas from her long-term memory. The other model, knowledge transforming, involves a higher thinking process that includes careful interaction between the content and the rhetoric dimensions to create the new text, a task more difficult than “telling.” The knowledge transforming strategy allows re-elaborating on the conceptual content as well as the text-linguistic forms, while the knowledge telling model is based on retrieving already known ideas and translating the ideas directly into text without adding any new information. Therefore, in the knowledge telling model, the sequence of the ideas presented in the text illustrates the writer’s connections among the retrieved ideas. On the other hand, the knowledge
transforming model is based on two-way interaction between the writer’s already existing knowledge, or “content space,” and the writer’s reflection on the knowledge, or the “rhetorical space” (Beretier & Scardamalia, 1987).

Additionally, Galbraith (1999) built a knowledge-constituting model in an attempt to explain the writer’s cognitive process. His model revolves around interaction between two spaces: the content space, which refers to the writer’s knowledge disposition, and the rhetorical space, which refers to the writer’s linguistic knowledge. The written text reflects the interaction between the writer’s content disposition and linguistic network to produce coherent text, which results in new knowledge through the creation of a new relationship (Galbraith, 1999). Galbraith’s model is almost identical to the knowledge transforming model except for one difference:

The two-way interaction (…) responsible for the transformation of thought in writing is between explicit problem-solving processes and implicit knowledge-constituting processes, rather than between two mental spaces, and involves two different kinds of transformation of thought rather than a single one. (Galbraith, 1999, p. 153)

In scientific writing, operating in the content space, which consists of both prior knowledge and new to-be-learned ideas, displays the writer’s reflection on the meaning of the new ideas, while operating in the rhetorical space ensures the communication of that meaning to the audience. Therefore, the writer’s knowledge is reformed by the recursive attention to match the content to the rhetorical goals of writing. According to Galbraith and Rijlaarsdam (1999), the writer’s ability to handle both the content space and the rhetorical space illustrates the second writing process, which is managing the
writing. Keys (1999) pointed out that the existence of such dynamic interaction between content and rhetorical requirements demonstrates the writing outcome and reveals the difference between novice and expert writing.

Interestingly, Klein (1999) suggested four hypotheses, which represent different aspects of writing. The first hypothesis, which is attributed to Britton (1982), suggests that writers generate knowledge spontaneously “shaping at the point of utterance” (Klein, 1999, p. 203), where free writing helps students to focus on their requirement to progress and on specific areas for improvement (Weiner, 1986). The second hypothesis, which is called “forward search” and is attributed to Young and Sullivan (1984), implies that writers externalize their ideas in text, then reread this text to generate new inferences. The “genre” (Klein, 1999, p. 203), the third hypothesis, in which he described how writing in scientific genres can generate new knowledge (Klein, 1999), attributed to Newell (1984), implies that writers use genre structures to organize relationships among elements and linking knowledge. The final hypothesis, attributed to Bereiter and Scardamalia (1987) and Flower and Hayes (1980), called “backward search” (Klein, 1999, p. 203), suggests that writers set rhetorical goals and then solve content problems to achieve these goals. Prain and Hand (1996) stated that students should be encouraged to write their understanding of science concepts in a variety of ways using their own language. Where Beall (1991) used in-class writing in his study to increase thinking and comprehension and for improving the communication between students and the large lecture class, and he found that most students in study responses was positive. Some of his students have responded particularly favorably to seeing the writings of other students, also some student in his study think that In-class writing forces him/her to think more about what
he/she am writing about, thus creating an improved understanding of it. Poock (2005) commented on the importance of writing in the study of chemistry:

Writing is extremely important in the chemistry curriculum…Writing in chemistry can accomplish more than one goal. While teaching students to write effectively as will be needed in their profession, the writing process itself is a means for the students to learn and understand chemical concepts. (p. 26)

Similarly, Rosenthal (1987, p. 996) suggested that there “is no question that students majoring in chemistry, and perhaps other sciences as well, graduate with underdeveloped writing skills.” Therefore, writing is required to address an insufficiency among chemistry students (Poock, 2005). While a handbook for teachers to promote writing in the chemistry curriculum was developed by Kovac and Sherwood (2001), several articles also have been published that describe the variety of ways writing has been integrated into the chemistry classroom (Gordon et al., 2001; Paulson, 2001; Shires, 1991). For example, in response to the many misconceptions about thermodynamics, Beall (1994) argued for the inclusion of writing tasks in thermodynamics lessons:

The conclusions reached by reading the in-class writings of students in thermodynamics provide evidence of the utility of this pedagogical tool in evaluating the students’ level of understanding and the misconceptions they hold during the teaching process. This is a powerful means for identifying student problems and misconceptions so that they can be remedied at the time. Showing good student writings to students during the next lecture can help clarify troublesome topics. (p. 1057).

Sutton (1996) has argued that students need to be given a variety of opportunities
to use language to explain and justify their understanding of science and scientific language. Prain and Hand (1999) and Hohenshell and Hand (2006) have also begun to address some of the issues arising as a consequence of students being asked to use different writing types as a means to construct an understanding of science. However, Strenski (1984) demonstrated writing as a proficient activity, where the writing is work as learning:

Writing is efficient: it works as learning. In labs, science teachers give students opportunities to learn science by experimenting with procedures and instruments. Writing can also let students experiment with concepts and processes. As they manipulate and test factual data on paper -as they write- they actively learn science. (p. 61)

Interestingly, Wallace, Hand, and Prain (2004) asserted that “writing is an essential activity that all students of science need to slot in to entirely focus their scientific understandings” (p. 2).

The Science Writing Heuristic

The National Science Education Standard (1996) obviously emphasizes that “learning science is an inquiry-based process,” since students experience enhanced learning when they construct their own knowledge following a learning cycle model and when they are actively engaged in the classroom (Farrell, Moog, & Spencer, 1999). Farrell, Moog, and Spencer (1999) believed that students learn better when the instructor acts as a facilitator to support groups in the learning process, which directs students to answer their questions themselves when the instructor doesn’t answer their question. A Consequence student constructs their knowledge and draw conclusions themselves by
analyzing data and discussing ideas, and they understand concepts and solve problems since they learn how to work together.

The implementation of inquiry-based teaching in classrooms has taken new sets of requirements (AAAS, 1993; NCR, 1996); in fact, several instructional models and templates have been developed (Bybee, 1997; Pizzini, 1996; Stepans, 1994) to assist teachers in implementing inquiry in their classrooms and labs. Additionally, instructional science laboratories are generally considered as a key component of science instruction where the non-science and science majors find laboratory-based activities to be motivating and exciting (Markow & Lonning, 1998). Even though laboratory work has enjoy long sequences of popularity, beginning in the 1970s the quantity and quality of college-level laboratory instruction began to turn down, reflecting a decline in interest in science as a career (Markow & Lonning, 1998; Pickering, 1993). Some features of laboratory work can merge to produce boring, step-by-step procedures which often give students training only in tedious manipulations. These features might be a result of several facts: instructional laboratories are often taught by graduate students, some of which have language problems (Pickering, 1993), little attempt is spent developing new experiments that make connections to students’ lives, and/or instructors have slight desire or experience in helping students learn (Markow & Lonning, 1998).

Hand and Keys (1999) developed the SWH as a tool to promote and scaffold scientific argumentation within science classrooms. The construction for designing the SWH includes the change to constructivist theory, understanding the nature of science, and supporting scientific literacy (Omar, 2004); besides “we use the science writing heuristic to organize how the laboratory classroom functions and how the students write
their laboratory reports” (Poock, 2005).

The SWH consists of a teacher template (Table 3) and a student template (Table 4). The students in SWH classes are required to construct laboratory reports. This laboratory report format consists of a series of questions constructed to help students deal with framing a research question, designing an experiment to answer the question, understanding experimental data and the science concepts associated with the experiment (Keys, Hand, Prain, & Collins, 1999; Omar, 2004; Poock, 2005). Also, there are two features of the SWH: the classroom dynamic during laboratory experiments, and writing laboratory reports as a key component of learning. Both parts are used together as a tool for successful understanding of chemical concepts in the laboratory (Kovac & Sherwood, 1999; Poock, 2005).

Table 3. A template for teacher-designed activities.

<table>
<thead>
<tr>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exploration of pre-instruction understanding</td>
</tr>
<tr>
<td>Pre-laboratory activities</td>
</tr>
<tr>
<td>Laboratory activity</td>
</tr>
<tr>
<td>Negotiation- individual writing</td>
</tr>
<tr>
<td>Negotiation- group discussion</td>
</tr>
<tr>
<td>Negotiation- textbook and other resources</td>
</tr>
<tr>
<td>Negotiation- individual writing</td>
</tr>
</tbody>
</table>

Table 3. A template for teacher-designed activities.
Moreover, the student template (Table 4) is a guide to scaffold students’ understanding of scientific concepts through the writing of the laboratory report by connecting 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 template prompts students to write beginning questions, claims, and evidence for claims. Next, students compare their laboratory findings with others, including peers and information in textbooks. Finally, the template asks students to write how their own ideas have been shaped, changed, or strengthened as a result of doing the experiment and writing the report (Poock, 2005).

The teacher template of the SWH provides strong pedagogical focus for implementing and conducting scientific investigation as a way to learn the scientific methods and procedures (Keys, Hand, Prain, & Collins, 1999; Omar, 2004). Poock (2004) set out eight possible activities associated with the laboratory experiment that included the teacher template:

(a) exploring pre-instructional ideas, (b) engaging in pre-laboratory writing activities, (c) doing the laboratory activity, (d) writing personal meanings for the laboratory data, (e) sharing personal interpretations of the data with peers in small groups, (f) comparing laboratory data with relevant ideas and/or known values in printed sources, (g) writing about how ideas have changed and writing a product for public viewing, and (h) doing post laboratory instruction that focuses on trends in the class data and the associated concepts. (p. 28)

The results of earlier SWH studies indicate that writing to learn in science activities can develop students’ conceptual understanding (Hand & Keys, 1999; Keys,
Table 4. Features of Students' SWH lab report.

- **Beginning questions or ideas**
  What are my questions about this experiment?

- **Tests and Procedures**
  What will I do to help answering 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?

- **Reflection/ Reading**
  How are my ideas compared with others?
  How have my ideas been changed?
  How my ideas can be compared with other groups?
  How is it compared to the textbook’s lecture?

Hand, Prain, & Collins, 1999), identify and resolve misconceptions students hold, encourage students to think logically and develop organizational skills (Lazarowitz & Tamir, 1994) and help students express their understanding of science by writing (Keys et al., 1999, Hand, Hohenshell, & Prain, 2007) so they will be able to learn science content. Additionally, a number of studies show that the implementation of the SWH has promoted students metacognition by engaging them to reflect on their knowledge, ability to create meaning from data, and understanding the nature of science (Hand, Hohenshell, & Prain, 2004; Hand, Prain, & Hohenshell, 2001; Keys et al., 1999, Poock, 2005).

Research has shown that inquiry is an effective teaching strategy with respect to attitudes, motivation, concept learning, and process learning (Abraham, 1998; Kern & Carpenter, 1984; Lawson, 1995; Rudd, Greenbowe, Hand, & Legg, 2001). For instance, students who followed the SWH have a strong perception of ownership toward learning, and
writing in the learning process (Grimberg, Mohammad, & Hand, 2004).

Further, using inquiry strategies in the classroom engages students in an active learning process (Farrell, Moog, & Spencer, 1999), creating an effective classroom dynamic heuristic (Omar, 2004). With the classroom dynamic related to constructivism where knowledge is constructed in the mind of the learner (Bodner, 1986). Teaching in the laboratory uses hands-on experiments and activities to engage students to become active in the learning process (Allen, Barker, & Ramsden, 1986; Farrell, Moog, & Spencer, 1999).

Few researches examine the gender differences in the general chemistry lab (Greenbowe & Hand, 2005; Poock, 2005) SWH has played a crucial rule in enhancing the females’ understanding and perceptions toward science; and, as Kahle (2004) states, that instead of blaming the female, gender is a response to the teaching environment; indeed, the SWH is a tool that can be utilized to change the teaching environment and affect the achievement gap between males and females. For instance, implementation of the SWH in chemistry courses allowed the difference in the achievement gap between males and females to be closed by utilizing SWH to change the teaching environment, where Females benefit by having an effective SWH instructor in that their scores on examinations develop more than males (Greenbowe & Hand, 2005).

Using the SWH, the difference in gender was significant in the beginning of the semester, but the difference in gender was not significant at the end of the semester (Poock, Burke, Greenbowe, & Hand, 2004). Additionally, Hohenshell (2004) indicated that “SWH females performed better after laboratory writing compared to SWH males and Control females; and as a group SWH students performed better than Control group
students on the test administered after summary report writing.” Similarly, Rivard and Straw (2000) found that discussion and writing together were more important than either individually completed tasks for performance and was particularly important for boys and that girls benefited more from peer discussion compared to writing alone.

This section integrated the previous findings of studies about students’ prior knowledge and their misconceptions in science, and particularly in chemistry, and introduced several factors that make the chemistry area one of the most difficult areas in science. In addition, literature on the gender gap in science and the need to close this gap by involving students in an effective environment was presented. Further, guided by current literature and findings from previous studies on the SWH approach and that this inquiry approach played a crucial role in terms of enhancing the females’ understanding and perceptions toward science, the study will investigate the following research questions. “Will implementing an inquiry approach (SWH template or approach) help freshman chemistry students better understand concepts and improve their perceptions of chemistry?”

To address this overarching question, the following questions guided my research:

1) What impact does the level of teacher implementation of the SWH (high or low) have on students’ conceptual understanding of heat transfer, solution calorimetry, and designing an experiment?

2) What impact does implementation of the SWH have on gender differences in students’ score of heat transfer, solution calorimetry, and their achievement in designing an experiment?
3) Do the two- and three-way interactions between teacher implementation level (high or low), students’ gender, and/or students’ achievement (bottom half and top half) have an impact on student scores on heat transfer, solution calorimetry, and their achievement in designing an experiment?

4) What impact does the implementation level of the SWH have on students’ perceptions about implementing SWH in the general chemistry lab including their perceptions about having control of lab activity, changing their ideas, and the value of the reflection component of the SWH template?

5) What impact does implementation of the SWH have on students’ perceptions about implementing SWH in the general chemistry lab including their perceptions about having control of the lab activity, changing their ideas, and the reflection component of the SWH template according to students’ gender?

6) What impact does implementation of the SWH have on students’ perceptions about implementing SWH in the general chemistry lab, including their perceptions about having control of the lab activity, changing their ideas, and the reflection component of the SWH template according to students’ achievement (top half and bottom half)?

7) What impact do the two- and three-way interactions between teacher implementation level (high or low), student gender, and/or student achievement (bottom half and top half) have on students’ perception about implementing SWH in the general chemistry lab including their perceptions about having control of lab activity, changing their ideas, and the value of the reflection component of the SWH template?
CHAPTER THREE

Research Method

General Overview

This chapter reviews the process used for the study and the rationalize for the choice of procedure and the data collecting techniques. Therefore, the chapter includes the context of the study, the sample of the study including the students and the teaching assistants from general chemistry lab in Midwest University, and a general overview about teaching assistant preparation and experience with the SWH.

Finally, the research framework is presented including the following: the qualitative research design with the observation as data collection method for this design and the criteria for teacher level of implementation and the ranking mechanism; and the quantitative research design with data collection and analysis methods including pre- and post- conceptual exams, lecture question, open-ended surveys.

The purpose of my research is to investigate what impact, if any, implementing the SWH approach in a general chemistry lab has on student understanding of specific heat, solution calorimetry, and designing an experiment and to assess the students’ ability and perceptions toward writing in science and implementing SWH while they are studying in a general chemistry lab, according to teacher level of implementing SWH, gender differences, and student achievement.

Context

This study was conducted in a large university in the Midwest of the United States
in a college freshman chemistry laboratory for non-science-major students. This research was based on a quasi-experimental mixed-method design. The general chemistry lab is related to a general chemistry course, and both the general chemistry course and the general chemistry lab were held in the same semester.

**Sample**

**Students:** Subjects in this study were students in a college general chemistry class for non-science major at a large university in the Midwest of the United States. A total of 153 students were enrolled in the laboratory portion of the course and 159 students were in the lecture portion of the course. Most of the undergraduate students were enrolled in the general chemistry lab and lecture course at the same time, so a total of 149 students took both the laboratory and the lecture and were potential subjects in the study.

Since some of the 149 students didn’t attend either the pre-conceptual exam at the beginning of the semester or the post-conceptual exam at the end of the semester, the researcher ended up with 142 students from those who attended both the lab and lecture component. The distribution of non-science-major students’ academic major was 58.3% in the College of Agriculture, 2.1% in the College of Business, 0.7% in the College of Design, 9.0% in the College of Education (now consolidated into the College of Human Sciences), 11.1% in the college Family and Consumer Sciences (College of Human Sciences), and 17.4% in the College of Liberal Arts and Sciences. Six teaching assistants (TAs) taught nine labs sections, with some TAs teaching two labs. The students heard a lecture about the thermodynamics (of heat transfer and solution calorimetry) before they did the experiment about thermodynamics.
**Instructors and Teaching Assistants:** Six teaching assistants taught nine laboratory sections using the SWH, and of the 6 observed TAs, three taught two laboratory sections each. The teaching assistants were primarily graduate students studying chemistry, but one was an undergraduate chemistry major. All TAs implemented the SWH in their labs, and the lectures sections were taught by the same instructor. Most students in the laboratory and TAs in the lab sections were observed by one observer, while the other observer observed two sections of the laboratory.

**Teaching Assistant Preparation and Experience of SWH:** In this study, all of the TAs in the study had experienced at least one semester of teaching in general chemistry lab, while most of the teachers (four TA’s) conducting the laboratory sessions had one semester experience of implanting SWH and minimal training during the TA training period prior to the beginning of the previous fall semester. One TA had experience training other TAs to use the SWH approach, but it was the first semester for this TA using the SWH approach in lab. And, one other TA had no experience of implementing SWH and no training beyond a couple of hours of discussion of implementing SWH at a staff meeting before the semester began. TA’s were given SWH notes and suggestions at each staff meeting throughout the semester. In addition, the two observers spent an entire period with each TA during a laboratory session to make specific suggestions for SWH implementation. In fact, one observer modeled correct implementation of the SWH by conducting the beginning of the laboratory session when requested by the TA in charge of that laboratory.

The students were introduced to the SWH approach via the mystery activity (Burke & Greenbowe, 2007, p. 1) (see Appendix A). The TAs had the students read the
activity, put them into groups of four to discuss beginning questions, had each group write a claim and evidence on the chalkboard, and then had each small group explain their reasoning to the entire class. After each group presented, students in the rest of the class could ask them questions or dispute something they claimed or argued. When all issues were resolved, the TA said: "If you could now ask the investigating team a question or ask them to conduct an additional test to explore the mystery further, what would it be?" The TA allowed them to talk for another five minutes or so and offer further questions to the entire class. Following this, the TA outlined the format of the SWH approach, explaining the different components (Beginning questions, Safety, Procedures, Observations, Claims, Evidence, and Reading and Reflection).

Each student attended one of these nine 2-hour 50-minute laboratory sessions each week. In addition, each student attended two 50-minute lectures, one Tuesday and one Thursday. Finally, they were scheduled to attend two 50-minute recitation (problem) sessions each week (one Monday and one Wednesday).

**Research Framework**
In this study, a mixed (qualitative and quantitative) approach to research was applied. Fraser and Tobin (1992) emphasized that gathering and analyzing both quantitative and qualitative data will add to the richness of the study.

**Qualitative Research Design**
Qualitative measures were used for observations of TAs and students in the laboratory. The implementation of each teacher was ranked and used to report the implementation level. For this purpose, teachers were observed during implementation by
two independent observers. Both observers were experienced in implementing SWH and ranking teachers’ implementation. One observer was a Ph.D. student in chemical education and the other observer was a Ph.D. student in curriculum and instruction, both observers had experience of teaching and implementing SWH in general chemistry lab. One observer observed all the TAs and went to each lab for the full three hours. The researcher only observed two lab sections and recorded one of these each week for further analysis, one of the two labs have been observed and video taped three hours each week and other TA have been observed through video taped.

At the end of the semester, the two observers independently ranked the TA’s SWH implementation levels. The inter-rater reliability or the percentage of agreement between the observers was above ninety percent.

Throughout the course of the semester, students were involved in 13 experiments, one experiment per week, and they wrote 13 laboratory reports in the SWH format. Two laboratory exercises were the focus of this study:

a. Experiment. 9: Investigating heat exchange in physical processes.

b. Experiment. 10: Investigating heat exchange in chemical reactions.

These two experiments are related to the three concepts, specific heat, solution calorimetry, and designing an experiment, which have been our focus in this study. For that reason, our ranking for the TAs depended on how the TAs implemented the SWH in these two labs.

*Ranking Mechanism.*

“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” (McMillan & Schumacher, 1997, p. 270). So, as I can’t observe everything, so it was valuable to decide, early on, the main aspects to focus upon throughout the observations (Omar, 2004).

Each teaching assistant was ranked based on his or her level of implementation based on the criteria matrix developed by Gunel (2006), using the previous work of Omar (2004) and Omar and Gunel (2004), on a range of high, medium, and low. The ranking mechanism consisted of three composite ranks, and three criteria to define teachers’ level of implementation were constructed. For more detail, please see Appendix B.

Based on the criteria, the observers ranked three TAs with a low level of teacher implementation, while the other three TAs were ranked with a high level of implementation. Please see table 5 below where these writing were used in the quantitative analyses.

**Levels of Teacher’s Implementation**

**High level of teacher implementation:**
Teaching assistants were rated at the end of the semester as either “High” or “Low” in their ability to successfully implement the SWH. The two observers noticed that the TAs ranked high in implementing the SWH approach gave the students opportunities to discuss beginning questions before they started working on their experiment. The TAs usually asked open-ended questions to create a dialogue and encourage interaction among the students and between the TA and the students about how they were going to design their own experiment to answer their beginning questions (promoting a sort of social constructivism). Further, the TAs encouraged the students
Table 5. Ranking information for each teacher

<table>
<thead>
<tr>
<th>Teacher name</th>
<th>Teaching experience As a TA</th>
<th>Implementing SWH experience</th>
<th>Had training besides the staff meeting</th>
<th>Number of lab sections taught this semester</th>
<th>TA rank for implementing SWH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jessica</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>1</td>
<td>High</td>
</tr>
<tr>
<td>Mark</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>1</td>
<td>Low</td>
</tr>
<tr>
<td>John</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>2</td>
<td>Low</td>
</tr>
<tr>
<td>Sarah</td>
<td>Yes</td>
<td>No</td>
<td>No (but she helped train TAs to implement SWH)</td>
<td>2</td>
<td>High</td>
</tr>
<tr>
<td>David</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>2</td>
<td>High</td>
</tr>
<tr>
<td>Michael</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>1</td>
<td>Low</td>
</tr>
</tbody>
</table>

to assign their own work groups as well as the tasks required to complete the laboratory experiment. Instead of answering students’ questions directly, the TAs usually responded by asking another question or redirected the original question to the whole class or to the students in one or two smaller groups.

Teacher management played a crucial rule in enhancing students’ learning while they were engaged in the SWH approach. Further, the structure for writing the laboratory notebook using the student template of the SWH approach was a key factor in student success. Most students came to class having preparing the pre-laboratory and safety
sections of the report. Completing these components helped engage students in the class discussion about the experiment. In addition to encouraging them to assign their own work groups as well as assign their own tasks, the TA explained and demonstrated laboratory techniques to provide students more of an understanding of what they needed to know while they were designing their own experiment.

A TA who was effective at implementing the SWH approach created a student-centered classroom where the role of the teacher was not that of directing the students. The students acted as mature learners. They created their own beginning questions that they wanted to answer by designing their own experiment. Then based on the data and the observations they had collected, they came up with their own claim and supporting evidence. They engaged in effective dialogue with their peers and with their teacher. Sometimes students encountered misconceptions while they were learning and experienced an appropriate scientific conceptual change process based on their discussion, communication, and argumentation with their peers. The TA interacted with the students without gender bias. Both females and males were equally engaged in the classroom and they had the same opportunity to discuss their findings. The effective TAs created a classroom environment where all the students were motivated to do their best. This was an important factor and enhanced the females’ and non-science majors’ understanding by improving their attitudes and perceptions toward science and writing to learn.

**Low level of teacher implementation:**
An ineffective TA usually asked yes-no questions and rarely posed extended response questions. Students did not have the opportunity to become involved in fruitful
discussion or ask questions. Frequently, the interaction was between the teacher and the students in a teacher-centered environment. In this scenario, students believed the teacher alone knew the answer.

A TA who implemented the SWH approach at a low level posed the beginning question for the students or directed the students how to choose beginning questions and rarely discussed them. When students prepared the pre-laboratory section of their report, it was considered as a task to have a grade assigned at the beginning of the laboratory session and not to enrich the pre-laboratory discussion. In a teacher-centered laboratory, students usually did not have the opportunity to design their own experiment. Rather the TA demonstrated what to do, and the students worked on the procedure as if following a cookbook experiment. Usually the TA wrote the students’ data on the board and all students entered these findings in their notebooks without negotiation. They generally wrote their claim and evidence after they left the laboratory so they missed a great opportunity to be involved in fruitful communication, discussion, and argumentation about them. When the teacher asked or told the students information directly, the students treated the teacher as a source of knowledge and did not think themselves.

In a teacher-centered classroom, the instructor did not guide them. Students were instructed to follow their teacher’s direct instruction. Some students did not prepare their laboratory reports since they did not realize the importance of this task.

An important difference between effective (high level) and ineffective (low level) TA implementation of the SWH approach, was that the students were engaged in a different quality of writing activities. In the more student-centered classroom, learners wrote their beginning questions, data, claims and evidence, and TAs had them reflect and
focus on the big ideas while they were involved in the laboratory activity. In addition, by writing their laboratory report following the SWH format, writing to learn enhanced their perception and understanding in the general chemistry laboratory.

**Quantitative Research Design.**

While the purpose of qualitative research approach was to rank implementation the teachers of SWH, this did not answer specific research questions. In fact, qualitative and quantitative methods were considered complementary. I anticipated the qualitative component would support analyzing the quantitative data, in general, to address the guiding research questions framed from the literature review. Therefore, a mixed-method, quasi-experimental, pre-post connectional exam design with two groups was used. In addition, data was collected using an open ended-survey regarding freshman non-science major students perceptions of implementing SWH in a general chemistry lab. The purpose of the quantitative component was to answer all research questions, which led me to achieve the purpose of study.

A main goal of a scientific “quantitative” research was to identify a causal relationship between two variables (Morgan et al., 2004), where the type of result anticipated from the question indicates a cause-and-effect relationship between two variables, where the independent variable (teacher level of implementation, students’ gender, and/or students’ achievement) causes the change or difference in the dependent variable (student understanding on conceptual questions, and students’ perceptions of writing in science and implementing SWH). Such a causal relationship is apposite for experimental design (Merriam, 1988). While the research in biological and physical
sciences have a true experimental design, it is difficult to design true experiments in educational research due to the impossibility of randomization, and/or unavailability of control group or comparison group. As a result, 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 total control of potentially confusing variables. Although they are different quasi-experimental designs, a nonequivalent groups pretest posttest design (McMillan & Schumacher, 1997) and untreated control group design with pretest and posttest (Cook & Campbell, 1979) are the most prevalent and useful designs in education since it is impossible to randomly assign subjects. 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 (Cook & Campbell, 1979; McMillan & Schumacher, 1997).

**Data Collection**

**Conceptual exam:** A pre- and post-conceptual exam was implemented for the study, which included open-ended conceptual questions regarding chemistry concepts related to the general chemistry laboratory for the non-science major-students. The concepts probed in the tests related to the concepts of designing an experiment, solution calorimetry, and specific heat, which were questions 3, 8, and 9 in on the conceptual exam. Respectively, these conceptual questions required students to relate and represent their prior knowledge of these chemistry concepts that were to be explored within their general lab. Importantly, both the pre- and post- conceptual exam were the same exam including the same conceptual questions with the same sequence, which enabled me to
investigate any improvement in students understanding of our central focus chemistry concepts (designing an experiment, solution calorimetry, and specific heat).

The students took the open-ended pre-conceptual exam instead of a multiple-choice format test. Multiple-choice examinations (multiple-choice formats) assess chemistry content knowledge, conceptual understanding, and problem-solving skills, but they do not assess students’ understanding or explanations through written explanation (Poock, 2005). All students were asked to complete a pre-conceptual exam at the beginning of the semester inside their lab sections, and as the students were involved in different lab sections on different days, it was impossible to have all students complete the pre-conceptual exams at the same time. The conceptual exams were graded by the instructor of the lectures that related to the lab and the researchers. Both graded the exam independently and the inter-rater reliability was above 95%. (see appendix C).

**Lecture exam question:** At the middle of the semester, students in the two lecture sections had been involved in a lecture exam and one of the questions in that exam was related to a conceptual question (titration process concept) to determine if any improvement their understanding occurred in the lecture portion. The same teaching assistants who taught the laboratory sections randomly graded the lecture exams, and, more specifically, this question. An advantage of using the lecture portion question (titration process concept) was that the grading of the question was independent of the implementation of the SWH in the laboratory. Besides, there was no connection between a student’s laboratory section and the lecture section she or he attended. Therefore, the grading in the lecture portion of the course is independent of implementation of the SWH by the teaching assistants in the laboratory as well as the level of student interaction in
the laboratory (see appendix D).

**Open-ended survey:** Students answered open-ended survey questions that examine their perceptions about implementing SWH at the end of the semester. In addition, students were asked to rank their response from 0 to 3, so the survey data could be used in quantitative analysis (see appendix E).

**Data Analysis**

In general, descriptive statistics and frequency distributions were produced using the SPSS Frequencies procedure to assess the accuracy of the data collected (Mertler & Vannatta, 2002). The SPSS Explore procedure was employed to examine whether outliers possibly could affect the results of the study; in addition, three statistical assumptions (Normality, Linearity, and Homogeneity of variance) were investigated to ensure the validity of statistical results (Mertler & Vannatta, 2002). Also, two different one-way analysis of variance (ANOVA) models were estimated prior to implementation of SWH in the general chemistry lab where the pre-conceptual exam students’ total score is the dependent variable in both cases and where the teachers’ level of implementation (high or low) and the students’ gender are the fixed factors. The purpose of these two analyses was to determine if there was any significant difference before the students became involved in the general chemistry lab. More details of the statistical analyses will be explained under each research question, where the quantitative approach in this study was used to answer the following research questions:

- What impact does the level of teacher implementation of the SWH (high or low) have on students’ conceptual understanding of heat transfer, solution calorimetry, and designing an experiment?
To answer this question, a one-way ANOVA was performed prior to the students’ involvement in a general chemistry lab where students’ pre-conceptual questions score was the dependent variable, and the teacher level of implementation (high and low) was the independent variable; this model was estimated for each concept (heat transfer, solution calorimetry, and designing an experiment). Subsequently, analysis of covariance (ANCOVA) was chosen as a statistical method where the students’ post-conceptual question score was the dependent variable and teacher level of implementation (high and low) was the fixed factor. To control for possible influence of pre-conceptual question that might impact students’ conceptual understanding, I used as covariates in the statistical analysis the pre-conceptual question score for each particular focused concept (designing an experiment, solution calorimetry, and specific heat).

- What impact does implementation of the SWH have on gender differences in students’ score of heat transfer, solution calorimetry, and their achievement in designing an experiment?

To answer this question, a one-way ANOVA model was estimated prior to students’ involvement in the general chemistry lab, where students’ pre-conceptual question score was the dependent variable and student’s gender was the fixed factor. Subsequently, ANCOVA was chosen as a statistical method, where students’ post-conceptual questions score was the dependent variable and students’ gender (female and male) was the independent variable. To control for possible influence of pre-conceptual questions that might impact students’ conceptual understanding, in the statistical analysis the pre-conceptual question score for each particular focused concept (designing an experiment, solution calorimetry, and specific heat) were used as covariates.
• Do the two- and three-way interactions between teacher implementation level (high or low), students’ gender, and/or students’ achievement (bottom half and top half) have an impact on student scores of heat transfer, solution calorimetry, and their achievement in designing an experiment?

To answer this question, two- and three-way ANCOVA was chosen as the statistical method, where students’ post-conceptual question score was the dependent variable with the covariates being the pre-conceptual question score for each particular focused concept (designing an experiment, solution calorimetry, and specific heat) and students’ gender, teacher implementation level, and students’ achievement were the fixed factors. To control for the possible influence of pre-conceptual questions that might impact students’ conceptual understanding, the pre-conceptual question score for each particular focused concept (designing an experiment, solution calorimetry, and specific heat) were used as covariates.

What impact does the implementation level of the SWH have on students’ perceptions about implementing SWH in the general chemistry lab, including their perceptions about having control of lab activity, changing their ideas, and the value of the reflection component of the SWH template?

To answer the question, a one-way ANOVA model was estimated where the scores of students’ responses to the survey questions were the dependent variables (having control of lab activity, changing their ideas, and the value of the reflection component of the SWH template) and the level of teacher implementation (high or low) was the fixed factor.
• What impact does implementation of the SWH have on students’ perception about implementing SWH in the general chemistry lab, including their perception of having control of the lab activity, changing their ideas, and the reflection component of the SWH template, according to students’ gender?

To answer this question, a one-way ANOVA model was estimated where the scores of students’ response to survey questions (having control of lab activity, changing their ideas, and the value of the reflection component of the SWH) were the dependent variables and the students’ gender was the fixed factor.

• What impact does implementation of the SWH have on students’ perceptions about implementing SWH in the general chemistry lab, including their perception of having control of the lab activity, changing their ideas, and the reflection component of the SWH template, according to students’ achievement (top half and bottom half)?

To answer this question, a one-way ANOVA model was estimated where the scores of students’ responses to the survey questions (having control of lab activity, changing their ideas, and the value of the reflection component of the SWH) were the dependent variables and the students’ achievement (bottom half and top half) was the fixed factor.

• What impact do the two- and three-way interactions between teacher implementation level (high or low), student gender, and student achievement (bottom half and top half) have on students’ perceptions about implementing SWH in the general chemistry lab, including their perceptions about having control of lab activity, changing their ideas, and the value of the reflection component of the SWH template?
To answer this question, two-way and three-way ANOVA models were estimated where the scores of students’ responses to the survey questions (having control of lab activity, changing their idea, and the value of the reflection component of the SWH) were the dependent variables and teacher implementation level (high or low), student gender, and/or student achievement (bottom half and top half) were fixed factors.

Summary

Chemistry is considered one of the most difficult school subjects for several different reasons: the abstraction of the nature of chemistry topics; students’ perceptions of the context of chemistry courses, which influences their learning; and instruction that fails to help students distinguish the concepts and relationships required to understand the chemistry subject matter. Accordingly, teachers have discovered that the use of writing has changed their classroom environment for the positive (Howard & Jamieson, 1995; Herrington, 1981). In fact, some of the objectives of the SWH approach are to improve student conceptual understanding and perceptions toward chemistry topics. This study aimed to define what impact, if any, implementing the SWH approach in a general chemistry lab has on student understanding in chemistry and perceptions of the writing to learn and SWH approach. To achieve the study goal, a variety of data collection procedures were used, such as observation, conceptual exams, lecture portion questions, and open-ended surveys. Further, a combined approach of quantitative and qualitative procedures was used to offer more support for the data collected from this study.
CHAPTER FOUR

Results

General Overview

While the qualitative component, including the results, were described in the methods chapter, this chapter focused on the results of the quantitative component that aim to answer all research questions and lead me to achieve the purpose of the study. In this chapter the quantitative results were obtained according to teacher level of implementing SWH, gender differences, and student achievement based upon students’ results on the pre- and post-conceptual exam on the concepts of specific heat, solution calorimetry, and of designing the experiment; also based upon students’ response in the survey.

Conceptual Exam

The students’ results on the pre-conceptual exam were used as a reference for evaluating students’ performance, which, in turn, was employed for classifying the students into two groups: bottom and top halves. Correspondingly, one-way analysis of variance (ANOVA) models were estimated to provide a quantitative measure of differences between these two groups. Test results are interpreted as significant if $p < .05$, marginally significant if $.05 < p < .10$, and not significant if $p > .10$. The Eta squared ($\eta^2$) is an index of the effect size, where the Eta square ($\eta^2$) for non-significant results is low.

Level of Teacher Implementation

The ANOVA model was estimated with the pre-conceptual exam scores and the level of teacher implementation (high or low) as the dependent and independent
variables, respectively. However, no significant difference was observed between the two
groups of students with high and low levels of SWH implementation ($F(1, 130) = 0.497,$
$p = 0.482, MSE = 8.416$). Thus, the effect of the teachers’ SWH implementation on
students’ understanding of the same chemistry concepts was evaluated based on the post-
conceptual exam that was performed at the end of the semester. Hence, the following
quantitative results were obtained for three different concepts based upon students’
results on the pre- and post- conceptual exam:

(1) Heat transfer and solution calorimetry during titration process

A one-way ANOVA model was estimated with the scores of pre-conceptual
questions that correspond to the titration process and the level of teacher implementation
(high or low) as the dependent and independent variables, respectively. However, no
significant difference was observed between the two groups of teachers with high or low
SWH implementation) ($F(1, 130) = 0.090$ $p = 0.764, MSE = 0.451$), where the students’
mean score for the low-level implementation ($M_L = 0.34, SE = 0.085$) was higher than the
mean score for the high-level implementation group ($M_H = 0.30, SE = 0.079$).

Further, a one-way analysis of covariance (ANCOVA) model was estimated with
the post-conceptual question (titration process) score as the dependent variable, the level
of teacher implementation of SWH (high and low) as the main effect, and the pre-
conceptual question (titration process) as a covariate. By the end of the semester,
statistically significant differences were observed. Results indicated that the covariate, the
pre-conceptual question score, significantly ($F(1, 117) = 10.812, p < 0.001, \eta^2 = 0.085$)
influenced the post-conceptual question score. Interestingly, by the end of the semester,
the mean score for the post-conceptual question (titration process) showed a notable
difference in the performance of students having a high level of SWH implementation, compared to a low level of SWH implementation. The results showed significantly higher main effects for the high-level students’ group than the low-level students’ group ($F(1, 117) = 7.538, p < 0.007, \eta^2 = 0.061$), where the high-level group ($M_H = 1.603, SE = 0.150$) outperformed the low-level group ($M_L = 0.950, SE = 0.184$) (see Figure 1).

Also, a one-way ANCOVA model was estimated with lecture question score related to the titration process and the level of teacher implementation (high and low) as dependent and independent variables, respectively, SWH as an independent variable, and the pre-conceptual question (titration process) as a covariate. Results indicated that the covariate, pre-conceptual question score ($F(1, 117) = 1.219, p = 0.272, \eta^2 = 0.010$), did not significantly influence the exam question score. The mean score for the lecture question (titration process) showed no significant difference in performance between students having a high level of teacher implementation of SWH compared to a low level of teacher implementation by the end of the semester. The results showed that the main effect for group was not significant ($F(1, 117) = 0.566, p = 0.453, MSE = 0.005; M_H = 11.188, SE = 0.453; M_L = 11.716, SE = 0.536$).
Figure 1. The effect of level of teacher implementation on student understanding (titration process)

(2) Heat transfer and solution calorimetry in physical processes (specific heat)

A one-way ANOVA model was estimated with the pre-conceptual question score that corresponds to the specific heat question and the level of teacher implementation (high or low) as the dependent and independent variables, respectively. Results revealed no significant differences between the two groups (high or low level of teacher implementation of SWH) ($F(1, 130) = 0.443, \ p = 0.415, \ MSE = 0.664$); hence, students’ mean score for the low-level teacher implementation ($M_{\text{low}} = 0.32, \ SE = 0.12$) was higher than for the high-level teacher implementation ($M_{\text{high}} = 0.20, \ SE = 0.087$).

On the other hand, a one-way ANCOVA also was estimated based on the data that were collected at the end of the semester, where the post-conceptual question on specific heat of metal score and level of teacher implementation (high and low) of SWH were employed as the dependent variable and fixed factor, respectively, and the pre-conceptual question score (specific heat) was a covariate. Interestingly, significant
statistical differences were observed. Results indicated that the covariate, the pre-conceptual question score, significantly \((F(1, 117) = 5.449, p < 0.021, \eta^2 = 0.044)\) influenced the post-conceptual question score. The mean score for the post-conceptual question (specific heat) showed a clear difference in performance by students who had a high level of teacher implementation of SWH compared to a lower level of teacher implementation by the end of the semester. Moreover, the results showed that the main effect for group is significant, where the high-implementation students scored better than the low-implementation students’ group \((F(1, 117) = 9.024, p < 0.003, \eta^2 = 0.072)\).

Accordingly, the high-level group \((M_H = 1.411, SE = 0.157)\) outperformed the low-level group \((M_L = 0.659, SE = 0.195)\) (see Figure 2).

(3) Designing the experiment

Similarly, the data obtained from designing the experiment at the beginning and at the end of the semester were subjected to one-way ANOVA. The pre-conceptual question

![Figure 2. The effect of teacher SWH implementation on student understanding (specific heat)](image-url)
(designing the experiment) and the post-conceptual question were employed as the
dependent variable at the beginning and end of the semester, respectively, and the level
(high or low) of teacher implementation of SWH was employed as the independent
variable in both cases. Results showed non-significant statistical differences among the
two groups (high or low level of teacher implementation of SWH) \( F(1, 130) = 0.076, \ p = 0.784, \ MSE = .368 \), where students’ mean score for low-level implementation \( (M_L = 0.32, SE = 0.0924) \) was higher than the mean score for the high-level group \( (M_H = 0.29, SE = 0.0628) \).

A one-way ANCOVA model was estimated with the post-conceptual question
(designing the experiment) score as the dependent variable, the level of teacher
implementation of SWH (high and low) as the main effect, and the pre-conceptual
question (designing the experiment) as a covariate. Results indicated that the covariate,
pre-conceptual question score significantly \( F(1, 118) = 9.255, \ p < 0.003, \ \eta^2 = 0.073 \) influenced the post-conceptual question score. The mean score for the post-conceptual
question (designing the experiment) showed no significant difference in performance of
students who had a high level of teacher implementation of SWH compared to a low
level of teacher implementation by the end of the semester. The results showed that the
main effect for group was not significant \( F(1, 118) = 1.546, \ p = 0.216, \ \eta^2 = 0.013 \),
where the high-level group \( (M_H = 1.109, SE = 0.118) \) outperformed the low-level group
\( (M_L = 0.876 \ SE = 0.145) \) (see Figure 3).
Designing the Experiment

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**Figure 3. The effect of teacher SWH implementation on student understanding (designing the experiment)**

**Gender**

Using the pre-conceptual exam score as the dependent variable and students’ gender as the independent variable, a one-way ANOVA model was estimated. The results showed that there is no statistically significant difference based on student’s gender ($F(1, 130) = 0.273, p = 0.602, MSE = 8.43$), where the mean score for males ($M_M = 6.7, SE = 0.38$) is higher than the mean score for females ($M_F = 6.44, SE = 0.32$).

In addition to recognizing the possible relationship between teachers’ implementation of SWH and students’ understanding of chemistry concepts, I also wanted to determine if these effects are due to students’ gender. Consequently, the following quantitative results were obtained for three different concepts based upon students’ pre- and post-conceptual exam results. Further ANCOVA analysis was conducted with two-way and three way interactions among the main effects.
(1) Heat transfer and solution calorimetry during titration process

A one-way ANOVA model was estimated with the pre-conceptual question score that corresponds to the titration process question and the students’ gender (male or female) as the dependent variable and fixed factor, respectively. Results revealed a statistically significant difference between females and males ($F(1, 130 = 4.155) p = 0.039, \text{MSE} = 0.664$), where the students’ mean score for males ($M_M = 0.43, SE = 0.0923$) is higher than the mean score for females ($M_F = 0.19, SE = 0.0644$).

Furthermore, a one-way ANCOVA model was estimated with the post-conceptual question (titration process) score as the dependent variable, students’ gender as an independent variable, and the pre-conceptual question (titration process) as a covariate. Results indicated that the covariate ($F(1, 117) = 69.008, p < 0.001, \text{partial } \eta^2 = 0.371$) significantly influenced the post-conceptual question score. The results showed that the main effect for gender was not significant ($F(1, 117) = 1.206, p = 0.274, \text{partial } \eta^2 = 0.010$), where students’ mean score for females ($M_F = 1.171, SE = 0.182$) outperformed the mean score for males ($M_M = 0.893, SE = 0.173$).

A 2 x 2 ANCOVA model was estimated to determine the effect of gender and teacher level of implementation on students’ post-conceptual question scores, controlling for pre-conceptual question scores. The main effects of gender ($M_M = 0.880, SE = 0.170; M_F = 1.014, SE = 0.192$) was non-significant ($F(1, 115) = 0.269, p = 0.605, \text{partial } \eta^2 = 0.002$), where the mean effect of teacher level of implementation ($M_L = 0.596, SE = 0.199; M_H = 1.299, SE = 0.158$) was significant ($F(1, 115) = 7.640, p < 0.007, \text{partial } \eta^2 = 0.062$). The interaction between gender and teacher level of SWH implementation was non-significant ($F(1, 115) = 0.320, p = 0.537, \text{partial } \eta^2 = 0.003$). However, the covariate
of pre-conceptual question score was significantly related to the dependent variable of post-conceptual question score \( (F(1, 115) = 75.540, p < 0.000, \text{partial } \eta^2 = 0.387) \).

A 2 x 2 x 3 ANCOVA model was estimated to determine the effect of teachers’ level of implementation, gender, and students’ achievement levels on post-conceptual question scores, controlling for pre-conceptual question scores. The main effect for teachers’ level of implementation was significant \( (F(1, 111) = 8.300, p < 0.005, \text{partial } \eta^2 = 0.070) \), where the high-level teacher group \( (M_H = 1.341, SE = 0.156) \) outperformed the low-level teacher group \( (M_L = 0.619, SE = 0.186) \). All other main effect results for student achievement \( (M_{bottom} = 0.912, SE = .177; M_{top} = 1.048, SE = 0.183) \) and gender \( (M_{female} = 1.005, SE = 0.189; M_{male} = 0.955, SE = 0.168) \) were not significant. Further, the interaction between gender and student achievement was significant \( (F(1, 111) = 4.822, p < 0.030, \text{partial } \eta^2 = 0.042) \), while the other two-way interactions were not significant, but the three-way interaction was marginally significant \( (F(1, 111) = 2.854, p = 0.094, \text{partial } \eta^2 = 0.025) \) (see Figures 4, 5, and 6). However, the pretest covariate was significantly related to the dependent variable of post-conceptual question score \( (F(1, 111) = 74.290, p < 0.001, \text{partial } \eta^2 = 0.401) \).
Estimated Marginal Means of Post test
At Gender = female

Estimated Marginal Means of post-test
At Gender = male

Figure 4. Three-way interaction of titration process

Figure 5. Three way interaction on student understanding of titration process
Furthermore, a one-way ANCOVA model was estimated with lecture question score related to the titration process and students’ gender as dependent variable and fixed effects, respectively, and the pre-conceptual question (titration process) as a covariate. Results indicated that the covariate, pre-conceptual question score, did not influence the post-conceptual question score \(F(1, 117) = 2.448, p = 0.120, \text{partial } \eta^2 = 0.020\). The main effect for gender was significant \(F(1, 117) = 5.092, p < 0.026, \text{partial } \eta^2 = 0.039\), but was in the direction of females \(M_{\text{female}} = 12.217, SE = 0.493\) outperforming males \(M_{\text{male}} = 10.652, SE = 0.477\).

A 2 x 2 ANCOVA model was estimated to determine the effect of gender and teacher level of implementation on student lecture question score, controlling for pre-conceptual question (titration process) as a covariate. The main effect of gender was significant \(F(1, 115) = 7.485, p < 0.007, \text{partial } \eta^2 = 0.061\), with females \(M_{\text{female}} = 12.611, SE = 0.530\) outperforming males \(M_{\text{male}} = 10.645, SE = 0.474\), while the mean
effect of teacher level of implementation ($M_{low} = 12.134, SE = 0.544; M_{high} = 11.123, SE = 0.446$) was not significant ($F(1, 115) = 2.066, p = 0.153, \text{partial } \eta^2 = 0.018$). The interaction between gender and teacher level of SWH implementation was not significant ($F(1, 115) = 2.142, p = 0.146, \text{partial } \eta^2 = 0.018$). However, the covariate of pre-conceptual question score was not significantly related to the dependent variable of lecture question score ($F(1, 115) = 2.822, p = 0.096, \text{partial } \eta^2 = 0.024$).

A 2 x 2 ANCOVA model was estimated to determine the effects of gender and students’ achievement (top half and bottom half) on student lecture test score (titration process), controlling for pre-conceptual question (titration process) score. The main effect of gender ($F(1, 115) = 4.985, p < 0.028, \text{partial } \eta^2 = 0.042$) was significant, where females ($M_{female} = 12.221, SE = 0.495$) outperformed males ($M_m = 10.666, SE = 0.479$), whereas the mean effect of student achievement ($M_{bottom} = 11.152, SE = 0.488; M_{top} = 11734, SE = 0.496$) was not significant ($F(1, 115) = 0.673, p = 0.414, \text{partial } \eta^2 = 0.006$). The interaction between gender and student achievement was not significant ($F(1, 115) = 0.570, p = 0.452, \text{partial } \eta^2 = .005$). However, the covariate of pre-conceptual test score was not significantly related to the dependent variable of lecture question score ($F(1, 115) = 1.696, p = 0.195, \text{partial } \eta^2 = 0.015$).

A 2 x 2 x 3 ANCOVA model was estimated to determine the effect of teacher level of implementation, gender, and students’ achievement on students’ lecture question scores, controlling for pre-conceptual question scores. While the main effect for gender was significant ($F(1, 111) = 7.240, p = 0.008, \text{partial } \eta^2 = 0.061$), where females ($M_{female} = 12.628, SE = 0.538$) outperformed males ($M_{male} = 10.663, SE = 0.481$), the main effects for student achievement ($M_{bottom} = 11.331, SE = 0.503; M_{top} = 11.960, SE = 0.524$) and
teacher level of implementation ($M_{\text{high}} = 11.126, SE = 0.451; M_{\text{low}} = 12.165, SE = 0.553$) were not significant. Further, the two-way interactions were not significant, and the three-way interaction effect results were not significant ($F(1, 111) = 0.010, p = 0.920$, partial $\eta^2 = 0.001$). However, the covariate of pre-conceptual test score was not significantly related to the dependent variable of post-lecture question score ($F(1, 111) = 1.906, p = 0.170$, partial $\eta^2 = 0.017$).

(2) Heat transfer and solution calorimetry in physical processes (specific heat)

A one-way ANOVA model estimated with pre-conceptual question (specific heat) score as the dependent variable and gender of the student as the independent variable showed a statistically significant difference between males and females, ($F(1, 130) = 0.103, p < 0.044$, $MSE = 1.186$), where students’ mean score for males ($M_{\text{Male}} = 0.43, SE = 0.098$) is higher than the mean score for females ($M_{\text{Female}} = 0.19, SE = 0.077$).

A one-way ANCOVA model was estimated with post-conceptual question (specific heat) score as the dependent variable, students’ gender as an independent variable, and the pre-conceptual question (specific heat) as a covariate. By the end of the semester, the results showed that the main effect for group was not significant ($F(1, 117) = 1.179, p = 0.280$, $\eta^2 = 0.010$), with females ($M_{\text{Female}} = 1.261, SE = 0.183$) outperforming males ($M_{\text{Male}} = 0.986, SE = 0.174$). Results indicated that the covariate, pre-conceptual question (specific heat) score, significantly ($F(1, 117) = 1.179, p < 0.014$, $\eta^2 = 0.010$) influenced the post-conceptual question (specific heat) score.

A 2 x 2 ANCOVA model was estimated to determine the effect of gender and teacher level of implementation on students’ post-conceptual question (specific heat) score, controlling for the pre-conceptual question (specific heat) score. The main effect of
gender ($M_m = .958, SE = 0.170; M_f = 1.132, SE = 0.192$) was not significant ($F(1, 115) = 0.460, p = 0.499, \text{partial } \eta^2 = 0.004$), whereas the mean effect of teacher level of implementation ($M_{low} = 0.683, SE = .202; M_{High} = 1.406, SE = 0.158$) was significant ($F(1, 115) = 7.936, p < 0.006, \text{partial } \eta^2 = 0.065$). The interaction between gender and teacher level of implementing SWH was not significant ($F(1, 115) = 0.013, p = 0.911, \text{partial } \eta^2 = .000$). However, the covariate of pre-conceptual question (specific heat) score significantly related to the dependent variable of post-conceptual test score ($F(1, 115) = 5.464, p < 0.021, \text{partial } \eta^2 = 0.045$).

A $2 \times 2$ ANCOVA model was estimated to determine the effect of gender and student achievement (top and bottom) on students’ post-conceptual question (specific heat) score, controlling for pre-conceptual question (specific heat) scores. The main effect of gender ($M_m = 0.995, SE = 0.168; M_f = 1.259, SE = 0.177$) was not significant ($F(1, 115) = 1.17, p = 0.282, \text{partial } \eta^2 = .010$), nor was the mean effect of student achievement ($M_{bottom} = 0.894, SE = 0.171; M_{top} = 1.360, SE = 0.174; F(1, 115) = 3.613, p = 0.060, \text{partial } \eta^2 = 0.030$). The interaction between gender and student achievement was significant ($F(1, 115) = 6.357, p < 0.013, \text{partial } \eta^2 = 0.052$) (see Figure 7), where the cell mean for female (bottom half) is ($M_{F-Bottom} = 1.335, SE = 0.248$), female (top half) is ($M_{F-Top} = 1.183, SE = 0.254$), male (bottom half) is ($M_{M-Bottom} = 0.454, SE = 0.236$), and male (top half) is ($M_{M-Top} = 1.536, SE = 0.239$). However, the covariate of pre-conceptual question (specific heat) score was significantly related to the dependent variable of post-conceptual question (specific heat) score ($F(1, 115) = 0.6251, p < 0.014, \text{partial } \eta^2 = 0.052$).
A 2 x 2 x 3 ANCOVA model was estimated to determine the effect of teacher level of implementation, gender, and student’s achievement levels (bottom half and top half) on post-conceptual test scores, controlling for pre-conceptual question (specific heat) score. The main effect for teacher level of implementation was significant ($F(1, 111) = 10.108, p < 0.002$, partial $\eta^2 = 0.083$), where the high-level teacher group ($M_{High} = 1.442, SE = 0.152$) outperformed the low-level teacher group ($M_{Low} = 0.659, SE = 0.194$). In addition, the main effect for student achievement was significant ($F(1, 111) = 5.335, p < 0.023$, partial $\eta^2 = 0.046$), where the top-half group ($M_{top} = 1.335, SE = 0.177$) outperformed the bottom-half group ($M_{bottom} = 0.766, SE = 0.171$), but the effect of gender ($M_{female} = 1.144, SE = 0.184; M_{male} = 0.957, SE = 0.164$) was not significant ($F(1, 111) = 0.581, p = 0.447$, partial $\eta^2 = 0.005$). Further, the two-way interaction between gender and teacher level of implementation was not significant, but the two way interaction between gender and student achievement was significant ($F(1, 111) = 6.291, p$)
< 0.014, partial $\eta^2 = 0.054$). Moreover, the three-way interaction was not significant ($F(1, 111) = 0.423, p = 0.517$, partial $\eta^2 = 0.004$) (see Figure 8 and 9). However, the covariate of pre-conceptual question (specific heat) score was significantly related to the dependent variable of post-conceptual test score ($F(1, 111) = 4.781, p < 0.031$ $\eta^2 = 0.041$).

Figure 8. Three-way interaction on student understanding of specific heat

Figure 9. Three-way interaction on student understanding of specific heat
(3) Designing the experiment

Founded on the results of the pre-conceptual question about designing the experiment, there were no statistically significant according to gender ($F(1, 130) = 0.265$, $p = 0.608$, $MSE = 0.368$), whereas students’ mean score for males ($M_{\text{male}} = 0.33$, $SE = 0.61$) is higher than for females ($M_{\text{female}} = 0.27$, $SE = 0.61$).

A one-way ANCOVA model was estimated with post-conceptual question (designing experiment) score as the dependent variable, the students’ gender (male or female) as independent variable and the pre-conceptual question (designing experiment) as a covariate. By the end of the semester, the results showed that the main effect for group did differ significantly ($F(1, 118) = 9.318$, $p < 0.005$, $\eta^2 = 0.073$), where females ($M_{\text{Female}} = 1.304$, $SE = 0.129$) outperformed males ($M_{\text{Male}} = 0.760$, $SE = 0.122$). Results indicated that the covariate, pre-conceptual question (designing experiment) score, did significantly ($F(1, 118) = 10.835$, $p < 0.001$, $\eta^2 = 0.084$) influence the post-conceptual question (specific heat) score.

A 2 x 2 ANCOVA model was estimated to determine the effect of gender and teacher level of implementation on students’ post-conceptual question (designing experiment) score, controlling for the pre-conceptual question (designing experiment) score. The main effect of gender ($M_m = 0.759$, $SE = 0.123$; $M_f = 1.252$, $SE = 0.140$) was significant ($F(1, 116) = 6.981$, $p < 0.009$, partial $\eta^2 = 0.057$), where the mean effect of teacher level of implementation ($M_{\text{low}} = 0.922$, $SE = 0.146$; $M_{\text{High}} = 1.089$, $SE = 0.115$) was not significant ($F(1, 116) = 0.801$, $p = 0.373$, partial $\eta^2 = 0.007$). The interaction between gender and teacher level of implementing SWH was not significant ($F(1, 116) = 0.388$, $p = 0.535$, partial $\eta^2 = 0.003$). However, the covariate of pre-conceptual question
(designing experiment) score was significantly related to the dependent variable of post-conceptual test score \((F(1, 116) = 10.404, p < 0.002, \text{partial } \eta^2 = 0.082)\).

A 2 x 2 ANCOVA model was estimated to determine the effect of gender and student achievement (top and bottom) on students’ post-conceptual question (designing experiment) score, controlling for pre-conceptual question (designing experiment) scores. The main effect of gender \((M_m = 0.767, SE = 0.119; M_f = 1.303, SE = 0.126)\) was significant \((F(1, 116) = 9.563, p < 0.002, \text{partial } \eta^2 = .076)\), as was the main effect of student achievement \((M_{\text{bottom}} = 0.808, SE = 0.128; M_{\text{top}} = 1.262, SE = 0.129)\) was significant \((F(1, 115) = 5.784, p < 0.018, \text{partial } \eta^2 = .047)\). The interaction between gender and student achievement was only marginally significant \((F(1, 116) = 3.010, p = 0.085, \text{partial } \eta^2 = .025)\) (see Figure 13). However, the covariate of pre-question (designing experiment) conceptual question (designing experiment) score was significantly related to the dependent variable of post-conceptual question (designing experiment) score \((F(1, 116) = 4.582, p < 0.034, \text{partial } \eta^2 = .038)\).

A 2 x 2 x 3 ANCOVA model was estimated to determine the effect of teacher level of implementation, gender, and student’s achievement levels (bottom half and top half) on post-conceptual test scores, controlling for pre-conceptual question (designing experiment) score. The main effect for teacher level of implementation was not significant \((F(1, 112) = 0.645, p = 0.424, \text{partial } \eta^2 = 0.006)\), where the high-level teacher group \((M_{\text{High}} = 1.081, SE = 0.113)\) outperformed the low-level teacher group \((M_{\text{Low}} = 0.934, SE = 0.114)\).

In addition, the main effect for student achievement was significant \((F(1, 112) = 5.085, p < 0.026, \text{partial } \eta^2 = 0.043)\), where the top-half group \((M_{\text{top}} = 1.231, SE = 0.137)\)
outperformed the bottom-half group ($M_{bottom} = 0.784, SE = 0.134$); moreover, the gender effect also was significant ($F(1, 112) = 7.215, p < 0.008$, partial $\eta^2 = 0.061$), where females ($M_{female} = 1.255, SE = 0.138$) outperformed males ($M_{male} = 0.760, SE = 0.122$). Further, the two-way interaction between gender and teacher level of implementation was not significant, but the two way interaction between gender and student achievement was significant ($F(1, 112) = 5.085, p < 0.026$, partial $\eta^2 = 0.043$. Moreover, the three-way interaction effect results was not significant ($F(1, 112) = 0.159, p = 0.691$, partial $\eta^2 = 0.001$) (see Figure 10, 11, and 12). However, the covariate of pre-conceptual question (designing experiment) score was significantly related to the dependent variable of post-conceptual test score ($F(1, 112) = 4.125, p < 0.045 \; \eta^2 = 0.036$).

Estimated Marginal Means of Post-Test Q.3

Figure 10. Two-way interaction on student understanding of designing experiment
Figure 11. Three-way interaction on student understanding of designing experiment

Figure 12. Three-way interaction on student understanding of designing experiment
Survey

The students in both high and low teacher implementation levels were asked to complete a survey to assess the effectiveness of the structure of the laboratory reports and their conceptions regarding SWH at the end of the semester using ratings of 3, 2, 1, and 0, where 3 = extensive and 0 = not at all extensive.

Survey Results (total response):

A one-way ANOVA model was estimated with the scores of the student responses to the survey questions and the level of teacher implementation (high or low) as the dependent and independent variables, respectively. However, no significant difference was observed between the two groups (high or low level of teacher implementation of SWH) ($F(1, 129) = 0.492, p = 0.484, MSE = 7.046$), whereas the students’ mean score for the high-level group ($M_{high} = 8.0633, SE = 0.3033$) is higher than the mean score for the low-level group ($M_{low} = 7.7308, SE = 0.3592$).

Gender (survey results):

Using students’ response to the survey as the dependent variable and the students’ gender as the independent variable, a one-way ANOVA model was estimated. The results showed that there was no statistically significant difference between male and female students ($F(1, 130) = .081, p = 0.776, MSE = 7.068; M_{female} = 8.000, SE = 0.3119; M_{male} = 7.8676, SE = 0.3417$).

Student achievement results (survey results):

According to student achievement (top half and bottom half), a one-way ANOVA model was estimated. The results showed that there was not a statistically significant difference between the two groups depending on student achievement ($F(1, 130) < 0.001$, ...
A three-way ANOVA model was estimated to determine the effect of teacher level of implementation, student gender, and students’ achievement on students’ responses to the survey. The main effect for gender was not significant ($F(1, 117) = 0.022, p = 0.882$, partial $\eta^2 < 0.001$); the main effect result for student achievement was not significant ($F(1, 117) = 0.309, p = 0.579$, partial $\eta^2 = 0.003$), and teacher level of implementation was not significant ($F(1, 117) = 0.886, p = 0.349$, partial $\eta^2 = 0.008$). Furthermore, the two-way interactions were not significant, but the three-way interaction effect results were significant ($F(1, 117) = 4.587, p < 0.034$, partial $\eta^2 = 0.038$) (see Figures 13 and 14).

Figure 13. Three-way interaction on students' responses to the survey
Estimated Marginal Means of Total survey
At Gender = male

![Estimated Marginal Means of Total survey](image)

**Figure 14. Three-way interaction on students’ responses to the survey**

**Survey Question 3 (changing students’ idea):**

A one-way ANOVA model was estimated with the scores of the students’ response to survey question 3 and the level of teacher implementation (high or low) as the dependent variable and fixed effect, respectively. The results showed no statistically significant difference between high or low level of teacher SWH implementation \((F(1, 129) = 0.010, p = 0.922, MSE = 0.894)\), where the students’ mean score for the low-level group \((M_{low} = 1.31, SE = 0.13)\) is higher than the mean score for the high-level group \((M_{high} = 1.29, SE = 0.11)\).

**Gender (question 3):**

Using students’ responses to survey question 3 as the dependent variable and students’ gender as the independent variable, a one-way ANOVA model was estimated. The results showed that no statistically significant differences existed between males and females \((F(1, 129) = 0.105, p = 0.746, MSE = 0.894; M_{male}= 1.32, SE = 0.12; M_{female}=\)
Student achievement results (question 3):

There was no statistically significant difference in students’ achievement between males and females ($F(1, 123) = 0.168, p = 0.682, MSE = 0.887; M_{bottom} = 1.35, SE = 0.12; M_{top} = 1.29, SE = 0.12$).

A three-way ANOVA model was estimated to determine the effects of teacher level of implementation, gender, and student achievement on student responses to survey question 3. The main effect for gender was not significant ($F(1, 117) = 0.301, p = 0.584$, partial $\eta^2 = 0.003$), the main effect results for student achievement was not significant ($F(1, 117) = 0.048, p = 0.827$, partial $\eta^2 < 0.001$), and teacher level of implementation was not significant ($F(1, 117) = 0.020, p = 0.887$, partial $\eta^2 < 0.001$). Furthermore, the two-way interactions were not significant, while the three-way interaction effect results were significant ($F(1, 117) = 4.464, p < 0.037$, partial $\eta^2 = 0.037$).

Survey Question 5 (having control of lab activity):

A one-way ANOVA model was estimated with the scores of students’ response to survey question 5 and the level of teacher implementation (high or low) as the dependent and independent variables, respectively. The results showed a statistically significant difference among between high and low level of teacher SWH implementation ($F(1, 129) = 5.157, p < 0.025, MSE = 0.925$), with students’ mean score for the high-level group ($M_{high} = 1.58, SE = 0.11$) is higher than the mean score for the low-level group ($M_{low} = 1.19, SE = 0.13$).

Gender (question 5):

Using students’ responses to survey question 5 as the dependent variable and
students’ gender as the independent variable, a one-way ANOVA model was estimated. The results showed that there was no statistically significant difference between males and females ($F(1, 129) = 0.300, p = 0.585$, $MSE = 0.959$; $M_{female} = 1.48$, $SE = 0.12$; $M_{male} = 1.38$, $SE = 0.12$).

**Student achievement results (question 5):**

According to student achievement (top half and bottom half), a one-way ANOVA model was estimated. There was no statistically significant difference in mean survey question 5 scores between high and low student achievement groups ($F(1, 123) = 0.480$, $p = 0.490$, $MSE = 0.959$; $M_{top} = 1.35$, $SE = 0.13$; $M_{bottom} = 1.48$, $SE = 0.12$).

A three-way ANOVA model was estimated to determine the effect of teacher level of implementation, gender, and student achievement on students’ responses to survey question 5. The main effect for gender was not significant ($F(1, 117) = 0.048$, $p = 0.827$, partial $\eta^2 = 0.004$), the main effect for student achievement was not significant ($F(1, 117) = 1.0419$, $p = 0.310$, partial $\eta^2 = 0.009$), and the main effect of teacher level of implementation was significant ($F(1, 117) = 6.422$, $p < 0.013$, partial $\eta^2 = 0.052$). Furthermore, the two-way interaction between gender and teacher level of implementation was marginally significant ($F(1, 117) = 3.342$, $p = 0.070$, partial $\eta^2 = 0.028$), while the other two interactions and the three-way interaction effect results were not significant (see Figures 15, and 16).
Estimated Marginal Means of Survey Q.5

At Gender = female

Figure 15. Three-way interaction on students' response to survey question 5.

Estimated Marginal Means of Survey Q.5

At Gender = male

Figure 16. Three-way interaction on student response to survey question 5.
Survey Question 6 (the value of the reflection component of the SWH template):
A one-way ANOVA model was estimated with the scores of students’ response to
survey question 6 and the level of teacher implementation (high or low) as the dependent
and independent variables, respectively. The results showed a statistically non significant
difference among between high and low level of teacher SWH implementation ($F(1, 129)$ = 5.157, $p = 0.761$, $MSE = 0.925$), with students’ mean score for the high-level group ($M_{high} = 1.42, SE = 0.10$) is higher than the mean score for the low-level group ($M_{low} = 1.37, SE = 0.14$).

Gender (question 6):
Using students’ responses to survey question 6 as the dependent variable and
students’ gender as the independent variable, a one-way ANOVA model was estimated.
There was no statistically significant difference between males and females ($F(1, 129)$ = 0.133, $p = 0.716$, $MSE = 0.924$; $M_{male}=1.43, SE = 0.12$; ($M_{female}= 1.37, SE = 0.12$).

Student achievement results (question 6):
According to student achievement (top half and bottom half), a one-way ANOVA
model was estimated. There was no statistically significant difference between the two
groups depending on student achievement ($F(1, 123) = 2.080, p = 0.152, MSE = 0.913$;
$M_{bottom}= 1.53, SE = 0.11; M_{top} = 1.29, SE = 0.13$).

A three-way ANOVA model was estimated to determine the effect of teacher
level of implementation, gender, and student achievement on students’ responses to
survey question 6. The main effect for gender was not significant ($F(1, 117) = 1.035, p =
0.311$, partial $\eta^2 = 0.009$), the main effect for student achievement was not significant ($F$
$(1, 117) = 1.608, p = 0.207$, partial $\eta^2 = 0.014$), and teacher level of implementation was
not significant ($F(1, 117) = 0.373$, $p = 0.542$, partial $\eta^2 = 0.003$). Furthermore, the two-way interaction between gender and teacher level of implementation was marginally significant ($F(1, 117) = 3.544$, $p = 0.062$, partial $\eta^2 = 0.029$), while the other two interactions were not significant. Also, the three-way interaction effect was marginally significant ($F(1, 117) = 3.004$, $p = 0.086$, partial $\eta^2 = 0.025$) (see Figures 17).

![Estimated Marginal Means of Survey Q.6](image)

**Figure 17. Two-way interaction for students' response to survey question 6.**

**Summary**

The quantitative results in this chapter have been presented in two parts depending on the results in the pre-post conceptual exam and the survey, while the qualitative results have been presented in the methods chapter, both qualitative and quantitative results were used as complementary to each other in order to answer the research questions to achieve the purpose of the study (see tables 6 and 7 below).
Table 6. The quantitative results related to the conceptual exam

<table>
<thead>
<tr>
<th>Independent Variables</th>
<th>Teacher level of implementation (high or low)</th>
<th>Gender</th>
<th>Two-way ANCOVA interactions*</th>
<th>Three-way ANCOVA interactions* (teacher level, gender &amp; student achievement)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-test score</td>
<td><strong>Non-significant</strong> (p = 0.482)</td>
<td></td>
<td>Non-significant (p = 0.602)</td>
<td>Marginal significant (p&lt;0.094) (see figures 4, 5, and 6).</td>
</tr>
<tr>
<td>Post-test score</td>
<td><strong>Non-significant</strong> (p = 0.764) M_L &gt; M_H</td>
<td></td>
<td>Non-significant (p = 0.274)</td>
<td>Non-significant (p&lt;0.013)</td>
</tr>
<tr>
<td>One-way ANOVA*</td>
<td>M_L &gt; M_H (see figure 7).</td>
<td></td>
<td>M_L &gt; M_H (p&lt;0.026)</td>
<td>Non-significant (p&lt;0.003)</td>
</tr>
<tr>
<td>Pre-test score</td>
<td><strong>Significant</strong> (p&lt;0.007) M_L &gt; M_H</td>
<td></td>
<td>Non-significant (p=0.046)</td>
<td>Non-significant (p&lt;0.044)</td>
</tr>
<tr>
<td>Post-test score</td>
<td><strong>Significant</strong> (p&lt;0.003) M_L &gt; M_H</td>
<td></td>
<td>M_L &gt; M_H (p&lt;0.005)</td>
<td>Non-significant (p&lt;0.013)</td>
</tr>
<tr>
<td>One-Way ANOVA</td>
<td>M_L &gt; M_H (see figure 1).</td>
<td></td>
<td>M_L &gt; M_H (p&lt;0.005)</td>
<td>Non-significant (p=0.044)</td>
</tr>
<tr>
<td>Post-test score</td>
<td><strong>Significant</strong> (p&lt;0.003) M_L &gt; M_H</td>
<td></td>
<td>M_L &gt; M_H (p&lt;0.005)</td>
<td>Non-significant (p=0.044)</td>
</tr>
<tr>
<td>One-way ANCOVA</td>
<td>M_L &gt; M_H (see figure 2).</td>
<td></td>
<td>M_L &gt; M_H (p&lt;0.005)</td>
<td>Non-significant (p=0.044)</td>
</tr>
<tr>
<td>Teacher level &amp;</td>
<td><strong>Non-significant</strong> (p = 0.453) M_L &gt; M_H</td>
<td></td>
<td>Non-significant (p=0.146)**</td>
<td>Non-significant (p&lt;0.003)</td>
</tr>
<tr>
<td>gender</td>
<td></td>
<td></td>
<td><strong>Non-significant</strong></td>
<td>(see figure 2).</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>Non-significant</strong></td>
<td>(see figure 7).</td>
</tr>
<tr>
<td>Teacher level</td>
<td><strong>Non-significant</strong> (p = 0.280) M_L &gt; M_H</td>
<td></td>
<td>Non-significant (p=0.146)**</td>
<td>Non-significant (p=0.920)**</td>
</tr>
<tr>
<td>&amp; student achievement</td>
<td></td>
<td></td>
<td><strong>Non-significant</strong></td>
<td>(see figure 6).</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>Non-significant</strong></td>
<td>(see figure 10).</td>
</tr>
<tr>
<td>Gender &amp; student</td>
<td><strong>Non-significant</strong> (p = 0.085)</td>
<td></td>
<td>Non-significant (p=0.911)</td>
<td>Non-significant (p=0.911)</td>
</tr>
<tr>
<td>achievement</td>
<td></td>
<td></td>
<td><strong>Non-significant</strong></td>
<td>(see figure 9).</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>Non-significant</strong></td>
<td>(see figure 11 and 12).</td>
</tr>
</tbody>
</table>

Conceptual exam

Heat transfer and solution calorimetry during titration process

Lecture portion (titration process)

Heat transfer and solution calorimetry in physical processes (specific heat)

Designing experiment
Table 7. The quantitative results related to the survey

<table>
<thead>
<tr>
<th>Independent Variables</th>
<th>Dependent variables (students’ Response to survey)</th>
<th>One-way ANOVA</th>
<th>Two-way ANOVA interactions*</th>
<th>Three-way ANOVA interactions*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total survey</td>
<td>Non-significant (p = 0.484) &lt;sup&gt;a&lt;/sup&gt; &amp; &lt;sup&gt;b&lt;/sup&gt;</td>
<td>Non-significant (p = 0.484) &lt;sup&gt;a&lt;/sup&gt;</td>
<td>Non-significant (p = 0.950) &lt;sup&gt;a&lt;/sup&gt; &amp; &lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Survey Question 3 (changing students’ idea)</td>
<td>Non-significant (p = 0.746) &lt;sup&gt;a&lt;/sup&gt; &amp; &lt;sup&gt;b&lt;/sup&gt;</td>
<td>Non-significant (p = 0.682) &lt;sup&gt;a&lt;/sup&gt;</td>
<td>Non-significant</td>
</tr>
<tr>
<td></td>
<td>Survey Question 5 (having control of lab activity)</td>
<td>Significant (p &lt; 0.025) &lt;sup&gt;a&lt;/sup&gt; &amp; &lt;sup&gt;b&lt;/sup&gt;</td>
<td>Non-significant (p = 0.495) &lt;sup&gt;a&lt;/sup&gt;</td>
<td>Non-significant (p = 0.070)</td>
</tr>
<tr>
<td></td>
<td>Survey Question 6 (the value of the reflection component of the SWH template)</td>
<td>Non-significant (p = 0.761) &lt;sup&gt;a&lt;/sup&gt; &amp; &lt;sup&gt;b&lt;/sup&gt;</td>
<td>Non-significant (p = 0.152) &lt;sup&gt;a&lt;/sup&gt;</td>
<td>Non-significant</td>
</tr>
</tbody>
</table>

\* The covariate is the pre-question score. ** The covariate is not significant, which means that the covariate didn’t significantly influence the post-conceptual question score.

\<sup>a</sup> The covariate is not significant, which means that the covariate didn’t significantly influence the post-conceptual question score.

\<sup>b</sup> The covariate is not significant, which means that the covariate didn’t significantly influence the post-conceptual question score.

Significant (p < 0.034) (see figures 13 and 14).

Significant (p < 0.037)

Significant (p < 0.950) (see figures 15 and 16).

Significantly (p = 0.086) (see figure 17).
CHAPTER FIVE

Discussion

General Overview

The purpose of this chapter is to address the impact of implementing SWH (inquiry-based approach) in a general chemistry lab on non-science-major students’ understanding of chemistry concepts and students’ perceptions toward writing in science and implementing SWH. A primary goal of the study was to draw attention to an important question: Will implementing an inquiry approach (SWH) help freshman chemistry students better understand chemistry concepts and enhance their perception toward writing-to-learn and implementing SWH in science?

The discussion within this chapter defines the main characteristics of the impact of implementing SWH on students’ conceptual understanding of chemistry concepts (specific heat, solution calorimetry, and designing an experiment) and on students’ perception toward writing in science and the SWH approach, according to teacher level of implementing SWH, gender differences, and student achievement, and the interaction between the three factors.

Enhancing Conceptual Understanding of Chemistry Concepts

Based on the qualitative and quantitative results, the researcher was able to establish some characteristics of the impact of implementing SWH in general chemistry labs on non-science-major students’ understanding of chemistry concepts (specific heat, solution calorimetry, and designing an experiment).
Levels of Teacher Implementation (high & low)

The two student groups (who were taught during the semester with a high or low level of teacher implementation of the SWH) started their academic year with statistically equal beginning prior knowledge of chemistry according to their results on a pre-exam. Furthermore, their prior knowledge about heat transfer and solution calorimetry concepts (specific heat, titration process, and designing an experiment) at the beginning of the semester, before implementing SWH in the general chemistry lab, were also statistically equivalent, where the students’ mean score for the low-level implementation was higher than the mean score for the high-level implementation group. At the end of the semester, the differences were statistically significant for both concepts (specific heat and titration process) and statistically non significant for designing an experiment, where the students’ scores in the group who had a teaching assistant rated with a “high” level of implementation SWH were statistically significantly higher than students' scores in the group who had a teaching assistant rated with a “low” level of implementing SWH. The difference in scores was statistically non significant for designing an experiment. The mean score for students who had a teaching assistant rated with a “high” level of implementing SWH was higher than for students who had a teacher with a “low” level of implementing SWH. The results suggest that students significantly benefit from having an effective teaching assistant implementing the SWH approach to improve their conceptual understanding of chemistry concepts (solution calorimetry and specific heat).

Gender Differences In Science (chemistry):

Female students started the semester with a statistically significantly lower level of conceptual understanding of chemistry concepts (titration process and specific heat)
than males. For the concepts related to designing an experiment, there was no statistically significant difference, although the mean score for males was higher than for females. At the end of the semester, after implementing SWH in the general chemistry lab, female students did earn statistically significantly better mean post-conceptual scores for designing an experiment and on lecture exam scores for titration process than males. There was no statistically significant difference in post-conceptual mean scores for titration process on lab exams, although the mean score for females was higher than for males. This suggests that the positive benefits to be gained from implementing the SWH approach in the chemistry lab for non-science-major students include the following:

1. Implementing the SWH approach helped to close the gap between males’ and females’ (titration process and specific heat) success.

2. The SWH approach enhanced females’ conceptual understanding of designing an experiment to a level higher than for males.

3. The approach changed females’ conceptual understanding (titration process) in the lecture portion from statistically significantly lower than males to statistically significantly higher than males.

Interestingly, at the end of the semester there was a two-way statistically significant interaction between gender and students’ achievement. The results were typical, in that high-achievement students scored better than low-achievement students, but our results show that low-achievement (bottom half), non-science-major female students enhanced their understanding of “specific heat” concepts, with mean effect ($M_{F_{Bottom}} = 1.335$) performance that was greatly higher than the mean effect for low-achievement (bottom half) non-science-major male students ($M_{M_{Bottom}} = 0.454$), higher
than the mean effect high-achievement (top half) non-science-major female students ($M_{F-Top} = 1.183$), and statistically slightly lower than the mean effect for high-achievement (top-half), non-science-major male students ($M_{M-Top} = 1.536$), after implementing SWH inside the general chemistry lab.

**Enhancing Students’ Perceptions Toward Implementing SWH**

Based on the quantitative results of ranked findings on an open-ended survey, the researcher was able to establish some of the characteristics of non-science-major students’ perceptions (having control of lab activity, changing their ideas, and the value of the reflection component of the SWH template) toward implementing SWH and the impact of implementing SWH in the general chemistry lab.

**Levels of Teacher Implementation (high & low)**

It is significant to note that students’ responses on the survey about having control of the activity (question 5) who were taught with a high level of implementation of the SWH had significantly higher mean responses than students who were taught with a low level of implementation of SWH. The mean score for total responses for students with a high-level TA was statistically significant higher than the mean score for total student responses with a low-level TA.

**Student Achievement in Science (chemistry)**

With regard to students’ total responses in the survey, is significant to note that there was no statistically significant difference between high-achievement students (top-half) and low-achievement students (bottom-half), where the mean score of the total response of both are equal. High-achievement students have more positive perceptions
toward science than low-achievement students, so I can conclude that the SWH approach significantly helped the bottom half close the achievement gap in science that existed at the beginning of the semester.

**Gender Gap Toward Science (chemistry):**

The literature review indicated that females’ attitudes and perceptions toward science are often less positive than those of males, but it is interesting to note that the non-science-major females’ perceptions toward implementing SWH (total response, having control of lab activity, and the value of the reflection component of the SWH template) in the lab were not significantly different from those of non-science-major males who also implemented the SWH while attending a general chemistry lab, where the mean score for females was higher than the mean score for males. I can conclude that the SWH approach significantly helped female close the gender gap in attitudes towards science that existed at the beginning of the semester.

**Gender, Level of Implementation, and Achievement Interaction:**

Interestingly, at the end of the semester there was a three-way statistically significant interaction result among gender, students’ achievement, and level of teacher implementation of SWH. It is typically known that males’ perceptions about science are more positive than females’, and low-achievement females (bottom half) have an especially low perception of science. It is important to note that our results demonstrated the mean for low-achievement (bottom-half) female’ ($M_{F-Bottom-H} = 8.70$, $SE = 0.583$) total response in the survey was higher than the mean for low-achievement (bottom-half) males ($M_{M-Bottom-H} = 7.833$, $SE = 0.615$) when both attended a general chemistry lab with a TA achieving a high level of SWH implementation; and higher than the mean effect for
low-achievement (bottom-half) females ($M_{F-Bottom-L} = 6.70, SE = 0.825$) and low-achievement (bottom-half) males ($M_{M-Bottom-L} = 8.071, SE = 0.697$) when both attended a general chemistry lab with a TA having a low level of implementing SWH. Moreover, the high-achievement (top-half) males ($M_{M-Top-H} = 8.562, SE = 0.652$) had greatly higher perceptions about science when they attended a lab with a high-implementing TA than did high-achievement males ($M_{M-Top-Low} = 7.529, SE = 0.633$) with low-implementing TAs.

Also, at the end of the semester there was a three-way statistically significant interaction result among gender, students’ achievement, and level of teachers’ implementation of SWH according to student response to survey question 3 (changing students’ ideas). It is important to note that the mean of low-achievement female students’ (bottom-half) response ($M_{F-Bottom-H} = 1.5, SE = 0.211$) was higher than the mean for low-achievement (bottom-half) males’ response ($M_{M-Bottom-H} = 1.333, SE = 0.222$), when both attended a general chemistry lab with a TA having a high level of implementing SWH. Moreover, the mean of low-achievement females ($M_{F-Bottom-H} = 1.5, SE = 0.211$) with a high-implementing TA was higher than low-achievement females ($M_{F-Bottom-L} = 0.900, SE = 0.298$) with a low-implementing TA. The results clearly indicate how significantly the females, specifically those in the low-achievement (bottom-half) group with a high-implementing TA, had high responses regarding their perceptions about SWH approach in general and more specifically about changing their ideas while involved in general chemistry lab. Their responses were superior to males and females in courses with a low level of SWH implementation.

The results clearly indicate how significantly students benefited from attending a
general chemistry lab with a high-implementing TA in their conceptual understanding of chemistry concepts and their perception toward writing to learn and implementing the SWH approach. In particular, low-achievement (bottom-half) females with a high-implementing TA had high responses regarding their perception about the SWH approach in general, and more specifically about changing their ideas and having control of their lab activity while involved in general chemistry lab, and their responses were superior to males and females in courses with a low level of SWH implementation. This is similar to results from previous studies suggesting that females can succeed in science on a par with males if females had been instructed on how to use skills to learn the course material (Kahle, 2004), where the efficiency of the laboratory depends on the approach in which the lab is taught (McKeachie, 1986). Indeed, Merritt, Schneider, and Darlington (1993) argued that students’ learning of chemistry would improved while they were successfully involved in planning the experimental approach because they need to understand what they were doing before, during, and after the lab; have a sense of ownership while they are designing their own experiment; and need to master the principles of the experiment to clarify what they are doing to one another while they are working together in the chemistry lab.

In fact, effective implementation of the SWH approach by the high-implementing TAs construct and enhance an effective environment in the classroom where the SWH approach (inquiry approach) is used as a framework; indeed, the SWH approach provides learners with a heuristic template to guide science activity and reasoning in writing. Further, the SWH approach provides teachers with a template of suggested strategies to enhance learning from laboratory activities, where the TA successfully arranges for
student- and teacher-centered instruction as needed. For example, the TA gave the
students the opportunities to discuss their beginning questions at the start of the lab
within each group, then among these groups, and finally with their TA; consequently, the
students engaged in meaningful discussions and were motivated to have discussions
between themselves and the teacher. However, the students answered these beginning
questions as a result of the TA explaining and demonstrating laboratory techniques first
and then guiding them, not directing them, to design their own experiment.

An effective TA usually enhances the collaboration of students with others to
build on their own ideas, and uses all levels of questioning depending on the status of
their discussion so the students interact with each other and construct their own idea.
They also encourage students to ask questions, by continuously asking them open-ended
questions and effectively responding to students’ questions to create dialogical
interaction in the classroom by asking another student for his/her opinion, thus extending
their answer. Guiding the students and giving them the opportunities to have discussions
in the high-implementing context of SWH will help encourage students to write their
thoughts or questions. Moreover, TAs who encourages students to choose their own
groups and tasks to complete the laboratory experiment was also focused on ensuring
that the class data were presented on the chalkboard. The data then were analyzed, and
the students are expected to write clearly what they have observed and what data they
had collected. The students then need to make a claim about what happened during the
laboratory and defend their own claim, and need to write their reflection section on how
their ideas have changed from their beginning questions or link the concepts from the
laboratory to the lecture portion of the course.
The effective TA usually pauses after asking a question to give the students the opportunity to think about the question before formulating a response (Blosser, 1975), asks open-ended questions, makes students think and create their own ideas, and listens closely to responses to assess what the students think (Penick, 1996). Teachers should have the students record the data they found on the chalkboard during the lab, and students should prepare written reports describing the rationale for the experimental design, the data, and their interpretations, which includes their lab reports following the SWH format. One of the purposes beyond writing is to communicate information with others (Galbraith & Rijlaarsdam, 1999), and most students struggle with the task of organizing ideas in their mind effectively (Galbraith, 1999).

The high-implementing TA helped students learn to create their own solutions to the problems of learning and become responsible for their own learning (Strachota, 1996) by inquiring about the students’ prior knowledge and creating a discussion environment for students by asking open-ended questions. Students in such an environment are often self-motivated and curious to make investigations, eager to discuss observations about designing their own experiments, and get used to the nature of scientific debate. For this purpose, students work in pairs or small groups to design their experiments, with negotiation of relationships between partners or among group members and collaboration so they were able build on their own ideas to answer the beginning question.

The high-implementing TA approach plays an important role in enhancing cooperative learning to improve students’ understanding of the topics because students who work in groups together on different activities tend to create a more comfortable atmosphere for quiet students. Within the systems perspective of communication, it is
assumed that the behaviors of participants mutually influence each other. The behavior of
the teacher is influenced by the behavior of the students, and in turn influences student
behavior (She & Fisher, 2000).

It is obvious that student understanding of chemistry concepts, enhancing student
cognitive understanding, and motivation toward writing to learn and implementing
SWH does not come unexpectedly or spontaneously; in fact, the SWH is an effective tool
and approach that enhances students’ understanding of chemistry concepts in both
laboratory and classroom contexts. The SWH organizes and promotes students’ critical
thinking, communication, self-confidence, and writing skills, as well as playing a role in
generating interest, motivation, and perceptions (Poock, Greenbowe, Burke, & Hand,
2004; Rudd, Greenbowe, & Hand, 2001; Grimberg, Mohammad, & Hand, 2004).

In a SWH classroom it is very important for students to display confidence,
respect, and a positive attitude. All of these aspects are very important for a student to do
well and understand the material. The more confidence students have, the better they will
do when faced with challenges. Many students perform poorly in the classroom not
because they have limited intellectual capacities but because they lack confidence in
themselves, and teachers are responsible for this because they should know their students
and support them when they lack confidence (Rousell, 1996). While it is known from
literature that girls often do not accomplish at a level equal to boys in science classrooms,
the literature also indicates the important influence of teaching environment and teacher
attempts on the gender gap. Most often, females receive less attention and interact less
with their teacher, and are given less freedom to call out in the classroom.

In fact, effective classroom environment questioning encourages ownership, helps
students interpret their observations, and links new learning to what students already know (Deal & Sterling, 1997). Creating a positive climate by sharing important and meaningful play and complimenting the students’ efforts will help students to build self-confidence and be more supportive and encouraging toward others (Halliday, 1999). The results clearly indicate how significantly students benefit from attending a general chemistry lab with a high-implementing TA in their conceptual understanding of chemistry concepts and their perception toward writing to learn and implementing the SWH approach. Particularly, the low-achievement (bottom-half) females with a high-implementing TA had high responses regarding their perception about the SWH approach in general.

This finding led me to conclude that the SWH approach played a crucial rule in enhancing the females’ understanding and perceptions toward science. Instead of blaming females for how they perceive and achieve in science, we should always remember that the gender factor is a response to the teaching environment (Kahle, 2004). When girls were in an effective teaching environment they perceived their teachers as more understanding and friendly, and they perceived their learning environment in a more positive way than the boys did (Rawnsley & Fisher, 1997; She & Fisher, 2000). In fact, the SWH approach is a tool that can be used to change the teaching environment and affect the achievement gap between males and females, helping females show better academic achievement in the lecture portion of the course.
Limitations and Implications

Limitations

Several limitations surround this study. The first limitation is that random sampling, one of the assumptions of the statistical analysis, was violated because all the students and the TAs in the general chemistry lab were involved in the study. Even though the research was conducted in a large university in the Midwest of the United States where most of the student came from different regions in the United States and some international students came from different countries in the world, the researcher was not able to assign students randomly to teachers and their classes. Generalization of the study findings is constrained by the fact that “in educational settings random assignment is rarely possible due to several organizational and cultural restrictions” (Gunel, 2006, p. 108).

The second limitation comes from the fact that non-science-major students usually take the general chemistry course, and particularly its lab, because it is a mandatory course and most students did not select the course out of personal interest. Markow and Lonning (1998) state that “The vast majority of students take chemistry as a required course for another discipline and are usually only motivated because they must obtain a passing grade in chemistry to continue in their chosen fields” (p. 1017). As a result, students often start the semester with a lack of motivation, background, and prior knowledge in chemistry, which places more pressure on the TAs and affects their SWH implementation especially at the beginning of the semester, in comparison to teaching science-major students who are typically highly motivated in general chemistry. To
reduce this limitation, our analysis concentrated on the last third of the semester, where students often begin to have positive attitudes about their involvement in the general chemistry lab.

The final limitation is subjectivity bias. Studying human phenomena has suffered from contamination related to the encouragement needed to motivate human participation, where interaction between the researcher and the participating teachers may have been influenced by encouraging teacher participation. However, for this study, the researchers and the other observer helped teachers with implementing SWH in their lab, which did not involve impressing the researcher’s ideas or knowledge on the teacher; rather, this reflected teachers’ understanding of the new teaching approach through their interaction with the researcher. To reduce subjectivity bias, another observer also interacted with the teachers, and the researcher used multiple data collection methods and scoring from an independent observer.

**Implications**

The results of this study provided a number of implications that could be categorized in two branches within the field of science education. There is a need for case studies that track students for a whole semester with different experiments, using multiple techniques for data collection in a qualitative design. The raw data collected from a case study provide depth and detail (Merriam, 1988). The study needs to develop and implement interviews and observations, and document techniques that can bridge observed teacher implementation level, observations, and responses to such techniques.

While longitudinal studies are difficult to do and uncommon, this study emphasizes the need for more studies. Additionally, a longitudinal study for more than
one semester for science and non-science-majors would enable me to track more teachers across time and to determine if the model of results with these teachers is characteristic.

Finally, since chemistry is considered one of the most difficult school subjects, students hold many misconceptions about different areas in chemistry, especially in thermodynamics. Such misconceptions influence how students learn new scientific knowledge and often turn out to be an obstacle in acquiring the accurate body of knowledge. The gender gap tends to enlarge and favor males as students get older starting from middle school levels. Accordingly, I recommend starting to implement the SWH approach in secondary and high-school chemistry courses to close the gap between the genders before it starts to widen, so students, especially female students, enter college with more positive attitudes toward chemistry and a more accurate understanding of the thermodynamics area.

**Summary**

Indeed, the efficiency of the laboratory depends on the approach in which the lab is taught (McKeachie, 1986). The use of the SWH approach as an inquiry-based tool in general chemistry labs helped students, who attended labs with a high level of SWH implementation (inquiry approach), to improve their understanding of chemistry concepts and their perception of implementing SWH and helped to close the gender achievement gap (Hohenshell, 2004; Poock, 2005), especially for low-achievement females by utilizing the SWH approach to change the teaching environment.

It is worth mentioning that implementing SWH for non-science major students was challenging, where the TAs were not confident to implement SWH inside general chemistry lab for non-science major students, and hence they thought that it would have
been implemented more efficiently for science major students. This attitude of TAs was raised based on the fact that the science major students’ motivation toward the general chemistry lab is higher than non-science major students, where the non-science major students have to register for this lab as a requirement for graduation, where the non-science usually have a lot of misconception in chemistry including thermodynamics.

In conclusion, implementing SWH approach has notably enhanced both male and female conceptual understanding and perception toward chemistry. It is well known that there is gender gap in science, where female have lower perception and self confident toward science. Interestingly, my findings have showed that implementing SWH helped closing the gap between male and female who started the semester with a statistically significant lower level of conceptual understanding of chemistry concepts among females than males. Importantly, implementing the SWH approach helped enhancing females’ conceptual understanding regarding designing an experiment to a level that is higher than that of males; also, implementing SWH changed females’ conceptual understanding in the lecture portion from statistically significantly lower than males to statistically significantly higher than males, including the low achievement non-science major students female.
REFERENCES

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52), Upper Saddle River, NJ: Prentice-Hall.


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Solving a Mystery: Observations, Claims, Evidence, and Conclusions
(Burke & Greenbowe, 2007)

You and your partner are private detectives who have been hired to investigate the
death of the wealthy but eccentric Mr. Xavier, a man who was well known for his riches
and for his reclusive nature. He avoided being around others because he was always filled
with anxiety and startled easily. He also suffered from paranoia, and he would fire
servants that he had employed for a long time because he feared they were secretly
plotting against him. He would also eat the same meal for dinner every night, two steaks
cooked rare and two baked potatoes with sour cream.

Upon arriving at the tragic scene, you are told that early this morning the servants
found Mr. Xavier dead in his home. The previous evening after the chef had prepared the
usual dinner for Mr. Xavier, the servants had been dismissed early in order to avoid
returning home during last night’s terrible storm. When they returned in the morning, Mr.
Xavier’s body was found face down in the dining room.

Looking into the room, you start your investigation. The large window in the
dining room has been shattered and appears to have been smashed open from the outside.
The body exhibits laceration wounds and lies face down by the table, and there is a large
red stain on the carpet that emanates from under the body. An open bottle of red wine and
a partially eaten steak still remain on the table. A chair that has been tipped over is next
to the body, and under the table is a knife with blood on it.
With this information, come up with a beginning question, a single claim to answer your beginning question, and supporting evidence for your claim.
## APPENDIX B

### Outline of Levels of Implementation Characteristics

(Sozan, 2004 & Gunel, 2006)

<table>
<thead>
<tr>
<th></th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
</tr>
</thead>
</table>
| **Dialogical Interactions** | • Communication is mostly from teacher to student, but rarely from student to student  
• Teacher uses IRE pattern (initiates, responds, evaluate) of questioning  
• Known answer | • Communication is usually from teacher to student, but occasionally from student to student  
• Teacher asks open-ended questions  
• Teacher response to students’ answers are non-evaluative but also non-probing | • Communication effectively varies from teacher to student and from student to student according to the situation  
• Teacher uses all levels of questioning and adjusts levels to individual students  
• Teacher response to students’ answer is probing—connects, extends, questions |
| **Management** (Focus of learning) | • Teacher plans only whole-class instruction  
• Teacher has difficulty with unexpected results  
• Teacher-centered  
• Teacher-controlled  
• Displays little confidence in SWH process  
• No student sharing of knowledge | • Teacher plans whole-class instruction, but occasionally uses small groups  
• Teacher begins to accept unexpected results  
• Teacher-centered, but occasionally student centered  
• Developing confidence in SWH  
• Student sharing in either small group, group to group, or whole group | • Teacher effectively plans whole class instruction as needed and frequently uses cooperative small groups  
• Teacher expects and anticipates unexpected results  
• Teacher effectively plans for teacher- and student-centered instruction as needed and appropriate  
• Obvious confidence in SWH approach  
• Student sharing with argumentation/connection in small groups, group to group and whole group—few prompts needed |
<table>
<thead>
<tr>
<th>Connections</th>
<th>Teacher does not recognize opportunities to make connections outside science</th>
<th>Teacher recognizes opportunities to make connections outside science, but doesn’t follow through</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Connection to big idea is absent or difficult to see</td>
<td>Connection to big idea is mechanical</td>
</tr>
<tr>
<td></td>
<td>Science activities do not promote big ideas</td>
<td>Science activities promote big ideas in a vague way</td>
</tr>
<tr>
<td></td>
<td>Language activities are add-ons</td>
<td>Language activities flow naturally throughout the SWH approach</td>
</tr>
<tr>
<td></td>
<td>Teacher does not build or activate student prior knowledge</td>
<td>Teacher builds or activates student prior knowledge but does not use information to make instructional decisions</td>
</tr>
<tr>
<td></td>
<td>Assessment does not align with intended or taught curriculum</td>
<td>Assessment somewhat aligns with intended or taught curriculum</td>
</tr>
</tbody>
</table>

- Teacher creates opportunities to make connections outside science and capitalizes on them
- Connection can be seen from beginning to end and articulated by students
- Science activities promote big ideas clearly and extend students’ learning
- Language activities, both planned and unplanned, evolve and enrich leaning as a result of SWH activities
- Teacher effectively builds or activates student prior knowledge with evidence of using to make instructional decisions
- Assessment aligns clearly and strongly with intended and taught curriculum
APPENDIX C
Pre- & Post- conceptual exam

Name___________________________Chem 163L Diagnostic Test  Section_________

1. (5 pts.) When we react some chemicals in the laboratory, the results seem to occur almost “instantly”. However chemical reactions, for example biochemical reactions, seem to occur slowly. Use what you “know” or have learned about rates of reactions and explain why some reactions occur instantly and some occur slowly?

2. (5 pts.) A student burns a piece of magnesium metal in an open crucible that is exposed to air; all of the metal turns to white powder substance. The mass is taken before and after burning. What do you think happens to the mass after burning (increase, decrease, or still the same)? Explain your answer.

3. (5 pts.) Design an experiment that would provide evidence that mass is conserved in a chemical reaction. Be very detailed in your explanation.

4. (6 pts.) The following “microbalance” can compare the mass of atoms. Here we compare two elements A (white) and B (black).

![Microbalance diagram]

a) Which element has an atom that is more massive? Please explain how did you choose your answer.

b) Which element A or B has more atoms per mole? Please explain how did you choose your answer.

c) Which element has fewer atoms per gram? Please explain how did you choose your answer.
5. (5 pts.) As a part of a laboratory experiment, students were used to prepare boiling water. One student used deionized water, and the other used tap water. Both forgot to check the volume of water after 15 minutes. When they did check, there was no water in their beakers. One had a clean beaker; the other had a beaker with a white structure on the bottom of the lower sides. Explain.

6. (5 pts.) The following represents a chemical reaction between oxygen, O₂ (white) and solid magnesium, Mg, (black). Assume a complete reaction Draw a diagram that represents what occurs after a reaction take place.

Write a balanced chemical reaction that represents the reaction.
7. (5 pts.) Two flasks have the same volume of solution, which one has the higher concentration. Explain your answer, incorporate the terms solute, solvent, morality, and density.

8. (5 pts.) Considering the following titration process, what is the expected temperature, (=20.0 °C, > 20.0 °C, < 20.0 °C)? Please explain your answer.

\[
\text{HCl}_{(aq)} + \text{NaOH}_{(aq)} \rightarrow \text{after mix}
\]

<table>
<thead>
<tr>
<th>Cocentration</th>
<th>3.0 M</th>
<th>3.0 M</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume</td>
<td>20.0 ml</td>
<td>20.0 ml</td>
</tr>
<tr>
<td>Initial temperature</td>
<td>20.0 °C</td>
<td>20.0 °C</td>
</tr>
</tbody>
</table>
9. (5 pts.) The following boxes represent a chemical reaction between AB\textsubscript{2} and B\textsubscript{2}?

What is the limiting reactant in this reaction, explain your answer.

10. (5 pts.) Considering the process of mixing two hot elements separately with water in a calorimeter.

<table>
<thead>
<tr>
<th>Case A</th>
<th>Case B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metal Al (Aluminum)</td>
<td>Water</td>
</tr>
<tr>
<td>Mass</td>
<td>10.0 g</td>
</tr>
<tr>
<td>Initial temperature</td>
<td>80.0 °C</td>
</tr>
<tr>
<td></td>
<td>20.0 °C</td>
</tr>
</tbody>
</table>

Specific heat for Al = 0.9 J/g °C  
Specific heat for Cu = 0.387 J/g °C

Final temperature Al =?  
Final temperature Cu =?

And after a period of time both the metal and the solution will reach a final temperature. Compare the final temperature (the same, higher, lower) of these two metals without doing any calculations. Explain your answer by words.
19. (16 pts) A common laboratory reaction is the neutralization of an acid with a base. When 50.0 mL of 0.500 M HCl at 25.0 °C is added to 50.0 mL of 0.500 M NaOH at 25.0 °C in a coffee cup calorimeter, the temperature of the mixture rises to 28.2 °C. Assume the mixture has a specific heat capacity of 4.18 J/g•°C) and that the densities of the reactant solutions are both 1.00 g/mL.

a) (3 pts) Write a balanced chemical equation for this reaction.

b) (4 pts) Is this reaction exothermic, endothermic, or neither. Explain.

c) (4 pts) Calculate the heat, q, associated with the chemical reaction.

d) (3 pts) What is the change of enthalpy per mole of the acid?

e) (2 pts) Identify what loses heat______________; what gains heat____________.
APPENDIX E

Survey

Name ___________________________ Chem 163L Spring 2005 Section_________

Please answer the following questions in order to help us assess the effectiveness of the structure of the laboratory reports. Complete answers will earn 5 bonus points. Use a rating scale of (3, 2, 1, 0 where 3 is extensive and 0 is not at all extensive)

1. To what extent did the beginning question/s help you to understand the point of the laboratory activity and or the experimental design? [3  2  1  0]. Why, explain?

2. To what extent did writing claim/s and evidence/s help you to understand the point of the laboratory activity and the concepts? [3  2  1  0]. Why, explain?

3. To what extent did your ideas change while you were doing any of the laboratory experiments and writing your laboratory reports? [3  2  1  0]. If so, how? Please give an example or two.

4. What has been most helpful or least helpful for you in using the Science Writing Heuristic for your lab report? Why? Please give an example or two.
5. To what extent you feel that you had control of what you chose to do for your experiment or how you designed your lab activities? [3  2  1  0]. Explain?

6. To what extent did doing the reflections portion of the laboratory report help you in understanding the laboratory experiment or the concepts associated with the laboratory experiment? [3  2  1  0]. How?

7. In your experience in Chem. 163L, did you do anything that helped you with the lecture portion of the course? If so, how? Provide examples. If not, explain why not.