COMPARING MALES’ AND FEMALES’ MOTIVATION TO LEARN SCIENCE USING A SCIENCE WRITING HEURISTIC

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The purpose of this National Science Foundation Funded (Robert Noyce Grant #0934731), mixed-methods study was to determine the difference between males’ and females’ motivation to learn science after employing a science writing heuristic in a secondary chemistry class for a semester. All students’ motivation to learn science and science self-efficacy increased from pre to post study, however females’ scores increased by a greater degree and they saw increases in science learning value, achievement goal, and performance goal subscales of the Student Motivation Towards Science Learning questionnaire (Tuan, Chin, & Shieh, 2005).

The AERA 2014 theme, “The Power of Education Research for Innovation in Practice and Policy” implies not only the need for relevant and timely research, it also indicates the need for practice to be linked to research and research to be linked to practice. It is through action research that practitioners inform their instruction by such linkages. Gable (1995) posits that action research involves acquisition of knowledge by participatory research. Through the process of action research, educational practitioners can have the opportunity to engage in praxis and improve their practices.

As a National Science Foundation funded teacher-researcher from 2010 – 2012 (Robert Noyce Grant #0934731), I implemented and researched the affects of using a science writing heuristic with my honors chemistry students. The decision to use a SWH was based upon several factors. First, it is an inquiry-based strategy that allows students to engage in science as scientists do, which the National Science Education Standards (NRC, 1996) and The Next Generation Science Standards (Achieve, 2013) recommend. Secondly, SWH engages students in discourse, writing, and reading, which allow students to construct a much deeper understanding of the content (Yore, Bisanz, & Hand, 2003; Keys, 2000). Thirdly, the literature shows strong evidence that using SWH teaches students the social and cognitive process associated with written discourse and can increase their understanding (Hand, Wallace, & Yang, 2004); students develop deeper, richer, and more specific understandings of the nature of science (Keys, Hand, Prain, & Collins, 1999); and implementing SWH notably enhances both male and female conceptual understanding and perception toward chemistry (Mohammad, 2007). Since there is a lack of research in the area of student motivation to learn science using a science writing heuristic, I felt that the results of my study could add to the body of knowledge. I also felt that engaging in science as scientists do would motivate my students to learn chemistry.

A science writing heuristic (SWH) is an instructional tool used by educators to promote problem-solving, critical thinking, communication, collaboration, and ultimately learning (Hand, et al, 2004; Keys, et al, 1999). It combines guided inquiry with writing-to-learn strategies. Students move away from the “cookbook” approach to laboratory experiences and participate in inquiry labs, draw inferences, and provide evidence from their investigation to support claims. They also use focused reflection to scaffold prior knowledge to new understandings, similar to what scientists do (Hand, et al, 2004; Burke, Hand, Poock, Greenbow, 2005; Akkus, Gunel & Hand, 2007; Yore, et al, 2003). Figure 1 shows a SWH
template used by the participants in this study to carry out laboratory experiences. Students included each part of the template in their Scientist’s Notebook to document their experience. This template was created by modifying the student and teacher templates used by Keys, Hand, Prain, and Collins (1999).

**Figure 1: Caukin SWH Template**

**Objective:** What is my question?

**Partners:**

**Safety:**

**Materials:**

**Procedure:** What will we do?

**Hypothesis:** What do I think will happen? If _, then _

**Observations:** What did I see? Describe in detail. There must be a table or graph with a title and an explanation. Show all equations, calculations, etc.

**Claims & Evidence:** Make claims based on what you experienced as it relates to your question. I can claim_____________because____________.

**Claims Shared:** Share results with other lab groups in class data table (with title and description) and an analysis of the data.

**Compare to Scientists:** Research what the scientific community says about your question. Write a summary of each source as it relates to your question. Have at least three credible sources cited.

**Reflection:** How have my ideas changed? Include your original hypothesis and state specifically which ideas have changed and why.

**Writing:** What is the best explanation of what I have learned? Be detailed.

**Opinion:** Express your opinion of your experience and why.

Using a SWH allowed my students to design laboratory experiences based on their questions, which were guided by science standards. As the teacher, I may have had a demonstration, a discrepant event, a photograph, a video clip or another means to pique student curiosity. Students were then encouraged to discuss and brainstorm in order to create testable questions that pertain to what they saw. The students were grouped according to similar questions, or if needed, grouped based on my discretion. The students then came up with a plan to answer their question. A materials list may have been provided in advance or left to the students’ creativity. Lab groups’ experimental designs had to be approved for safety, meeting the objective of the laboratory experience, and for necessary materials. Students identified all safety concerns and steps to minimize and manage risks. They had to have a plan to collect, record, and analyze their data.

Once the students had my approval, they began conducting their experiment. As the students collected and recorded their data, they also recorded their observations in detail, what they saw, heard, smelled, and experienced. Under the Observation section of the lab, data table(s) and written descriptions of those tables were constructed. As the students were conducting their experiments, I circulated and asked the students questions that required them to explain their understandings of what they were doing and what they were experiencing.
After the data collection and observations were made, the students then made claims based on the evidence of their observations (Claims & Evidence). Next the students shared their data (Claims Shared portion of the modified template). A class data table was created on the white board in the front of the room. Each lab group recorded their data. Students copied this class data table into their Scientist’s Notebook (where all notes, labs, and activities are recorded -a process-folio). As a class, the data were analyzed for trends and possible outliers. The students discussed the implications and then wrote about what the class data meant in their own words.

After analyzing and summarizing what they had learned as a class, the students compared their results to the scientific community (Compare to Scientists portion of the modified student template). They were allowed to use their textbook, Internet, or other credible sources. At least three different sources are required. A brief description of what they researched for each source was indicated and if their analysis was the same, similar, or dissimilar to what they experienced. All sources are required to be cited APA style.

After the Compare to Scientists section, comes the Reflection portion of the template. This is based on the student’s hypothesis. They restated their hypothesis and discussed if their ideas had changed and why. This section is a narrative that requires elaboration.

Following the Reflection is the Writing portion of the template. Students explained what they had learned as it related to their original question, what they had learned about the process of conducting the experiment, what they had learned about themselves and their lab partners, and what they had learned about what it means to do science.

Finally students give their opinion about the lab; what they liked about the lab, what they did not like about it, and what they would change if they could go back and redo it.

**Theoretical Framework**

The theoretical frameworks of this study are cognitive, contextual and social constructivism. Constructivism uses the metaphor of construction due to the nature of building knowledge. This knowledge must be built on a foundation, which represents the context on which the knowledge is built. The act of writing requires thinking about what and how one is going to write, the context in which it is written, and the social aspects of the language that is used to write. The cognitive processes utilized in writing are complex and require students to select, assimilate, organize, and construct thoughts and information (Cobern, 1991; Hoover, 1996; McMahon, 1997). Writing-to-learn can best be described as an interactive-constructive approach to learning as it involves individual, contextual, and social negotiation of language to construct meaning through writing. The act of writing is mostly personal; however what and how one writes is within a social and cultural context (Hohenshell & Hand, 2006).
Research Questions

The quantitative research questions were, “How will using a science writing heuristic affect honors chemistry students’ motivation to learn science?” and “Is there a difference in motivation to learn science between males and females after engaging in a science writing heuristic?”

The qualitative questions that guided this study were:
1. What are student perceptions of how using a science writing heuristic helped them learn?
2. What are student perceptions of what they gained by having to design their own laboratory experiences?
3. How did using a science writing heuristic impact students’ self-confidence to learn new science concepts?

Methods and Instrumentation

A sequential, explanatory mixed-methods design was used for this study. This design is characterized by the collection and analysis of quantitative data followed by the collection and analysis of qualitative data, with priority given to the quantitative data (Creswell, 2003).

Quantitatively motivation was measured pre and post using Tuan’s, Chin’s, and Shieh’s (2005) “Student Motivation Towards Science Learning” questionnaire (SMTSL). This is a 5-point Likert-type questionnaire consisting of six subscales that include: self-efficacy, active learning strategies, science learning value, performance goal, achievement goal, and learning environment stimulation. The authors define self-efficacy as students’ belief in their ability “to perform well in science learning tasks” (p. 643). Active learning strategies pertain to students constructing new knowledge from previous understandings by actively employing a variety of learning strategies. Science learning value involves students recognizing the benefits of learning science as it relates to problem-solving competency, participation in inquiry activities, the stimulation of individual thinking, and the relevance of science in daily life. Performance goal involves extrinsic motivation and relates to the student’s goal to compete with other students and gain attention from the teacher. Achievement goal involves intrinsic motivation and is defined as the satisfaction that students feel when they “increase their competence and achievement during science learning” (p. 643). Learning environment stimulation refers to the curriculum, teaching style, and student interaction in the classroom that influences the students’ motivation to learn science.

For the qualitative portion of this study, students were given a teacher-made, open-ended survey that was completed at the end of the study. These surveys were analyzed as well as students’ “Scientist Notebooks” where their initial ideas were recorded, took notes, and used the science writing heuristic during their laboratory investigations.
Participants

The participants in this study were in one of three high school honors chemistry classes from a small, rural, pre-kindergarten through 12th grade school in Middle Tennessee. All honors chemistry students were invited to participate. Fifty-six students participated in the study. One student was African American, two students were Latinas, and fifty-three students were Caucasian. Thirty of the students were female and twenty-six were male. Ten of the fifty-six students were considered to be of low socioeconomic status as determined by their free or reduced lunch status and forty-six did not receive free or reduced lunch. The following is the grade point average (GPA) breakdown: two students were in the 2.0 - 2.4 category, thirteen students were in the 2.5 - 2.9 category, eighteen students in the 3.0 - 3.4 category, and twenty-three students in the 3.5 - 4.0 category.

The American Diploma Project recommends that all students take chemistry or physics to graduate high school. This school offers honors chemistry (not standard, advanced honors, or advanced placement chemistry) and principles of technology (vocational physics). More students at this school take honors chemistry rather than principles of technology. Most of the students who take honors chemistry are juniors in high school, although some sophomores and some seniors are enrolled. The honors chemistry students tend to be on a path to college and on average have slightly higher grade point averages than those students who take principles of technology rather than honors chemistry at this school.

Science Instruction

During this study, students engaged in chemistry curriculum that included the following topics: laboratory safety, laboratory equipment, the scientific method, accuracy and precision, significant figures and scientific notation, properties of matter, physical and chemical changes, the atom, the periodic table, chemical bonding, and chemical nomenclature. Students employed the science writing heuristic throughout the semester.

Quantitative Results

From pre-SMTSL (Student Motivation Towards Science Learning) questionnaire to post SMTSL-questionnaire, student motivation to learn science for the entire group increased by about 3% (mean pre-SMTSL = 3.69, mean post-SMTSL = 3.80). In regards to gender and overall motivation to learn science, there were no statistically significant differences between males and females; however, females did statistically increase their post-SMTSL questionnaire scores on average by about 4% (mean pre-SMTSL questionnaire = 3.67 and mean post-SMTSL questionnaire = 3.83).

On the Self-Efficacy portion of the SMTSL, there was an overall increase from pre-test (M = 3.70) to post-test (M = 3.89). This indicates a 5% change in students’ confidence in their ability to engage in science.

On the Achievement Goal portion of the SMTSL questionnaire, females increased their score by about 3% (mean pre-AG = 3.98 and mean post-AG = 4.10) and males decreased their score by roughly 2.5% (mean pre-AG = 3.91 and mean post-AG = 3.81). Females also
increased their Science Learning Value score from pre to post-SMTSL by about 6% (pre-SLV = 3.71 and post SLV = 3.94). There was also an 8% increase from pre to post-Performance Goal portion of the SMTSL for females (mean pre-PG = 3.21, mean post-PG = 3.46). Table 1 shows a summary of the quantitative data.

Table 1

Summary of Pre and Post-SMTSL Data

<table>
<thead>
<tr>
<th>Test</th>
<th>Group</th>
<th>Statistically Significant</th>
<th>Mean Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-SMTSL</td>
<td>Whole Group (pre to post)</td>
<td>yes</td>
<td>$M = 3.69$</td>
</tr>
<tr>
<td></td>
<td>Male &amp; Female</td>
<td>no</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Females (pre to post)</td>
<td>yes</td>
<td>$M = 3.67$</td>
</tr>
<tr>
<td>Post-SMTSL</td>
<td>Whole Group (pre to post)</td>
<td>yes</td>
<td>$M = 3.80$</td>
</tr>
<tr>
<td></td>
<td>Male &amp; Female</td>
<td>no</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Females (pre to post)</td>
<td>yes</td>
<td>$M = 3.83$</td>
</tr>
<tr>
<td>Pre to Post</td>
<td>Whole Group Pre</td>
<td>yes</td>
<td>$M = 3.70$</td>
</tr>
<tr>
<td>Self Efficacy</td>
<td></td>
<td></td>
<td>$M = 3.89$</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-Achievement Goal</td>
<td>Gender</td>
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<td>Female ($M = 3.98$)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Male ($M = 3.91$)</td>
</tr>
<tr>
<td>Post-Achievement Goal</td>
<td>Gender</td>
<td>yes</td>
<td>Female ($M = 4.10$)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Male ($M = 3.81$)</td>
</tr>
<tr>
<td>Pre-Science Learning Value</td>
<td>Females</td>
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<td>pre ($M = 3.71$)</td>
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<tr>
<td>Post-Science Learning Value</td>
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<td>post ($M = 3.94$)</td>
</tr>
<tr>
<td>Pre-Performance Goal</td>
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<td>pre ($M = 3.21$)</td>
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<tr>
<td>Post-Performance Goal</td>
<td>Females</td>
<td>yes</td>
<td>post ($M = 3.46$)</td>
</tr>
</tbody>
</table>
Qualitative Results

For the qualitative portion of this study, students responded to a teacher-made, open-ended survey asking them their thoughts on if using the science writing heuristic helped them to learn, and if so, how? Following is a breakdown of themes within the survey and student responses.

Student Perceptions of Learning While Using the SWH

On the Student Opinion Survey, students wrote if they felt using the science writing heuristic (SWH) helped them to learn, and if so, how. By far, the majority of the students expressed that the writing portion of the lab helped them learn; either science concepts, how to conduct a laboratory experiment, how to collect and organize data and data tables, problem-solve, think outside of the box, think deeply, focus on the topic, reflect, and think for themselves.

How Using Writing in the SWH Helped Learning

Students were asked “What did the writing portion of the lab do for you in terms of your learning? Why?” Students’ responses included statements like “making me think about what has happened and making me express it in words [helped me to learn]” (female). One student (male) wrote, “[writing] Helped me to think about what I learned, by getting it all on paper, everything I learned resurfaced on paper.” A female student wrote, “[I learned] Reasoning, it wasn’t just about finding an answer, it showed me how to explain that answer.” Some students commented that using SWH taught them to be more independent and to “think like a scientist.” Many said that it made them reflect which helped them to learn.

Student Perceptions of What was Gained by Designing Labs

Students were asked, “What, if anything, did you gain by having to design and carry out your own labs.” Students expressed that designing their own labs helped them to better understand the point of the lab, what to do, and why they were doing it. They also wrote that they learned independence, organization, leadership skills, how to solve problems on their own, and to take on more responsibility. Some even wrote that they learned how to make mistakes and how to learn from their mistakes and the mistakes of others. Connections were made and expressed regarding gaining a better understanding of how scientists work.

Student Perceptions of Their Confidence to Learn New Science Concepts

Students were asked “How confident are you in your ability to learn science concepts? Why?” Several students indicated that their sense of self-confidence as it relates to science stems from their affinity for science, others expressed that it is intrinsic, i.e. if they work at it, they can learn it. Students tended to respond to this question based on whether they thought they were “good at science” or not. They were also asked “In terms of your attitude towards science and your confidence in your ability to do science, how would you compare the way we did labs during this study to the labs in other classes?” Students tended to respond that their confidence increased as the year went on. Some said that they felt more confidence in this class than other classes because they knew what they were doing and they felt good about it.
The quantitative data indicate areas of growth, areas of decline, and areas of no change as it relates to motivation to learn science. The qualitative data indicate student’s perceptions of how their learning and confidence were affected by using a science writing heuristic.

**Limitations**

This study is rife with limitations. First, the sample size was small – fifty-six students, thirty females and twenty-six males. Second, the study was conducted in one teacher’s classes and only in the honors chemistry classes; although no other chemistry courses are offered at this school. Third – the study occurred over an eighteen-week period (the first semester of instruction), rather than over the entire course. The results ultimately are specific to this sample, however they were meaningful to informing practices and improving instruction of the teacher.

**Scientific Significance**

The *National Education Science Standards* (NRC, 1996) and the *Next Generation Science Standards* (Achieve, 2013) recommend that students move away from a “cookbook” approach to science and engage in experiences where students apply inquiry processes and make connections between their explanations, evidence and their questions. Students need to ask the questions, investigate, and have supportive evidence for claims and compare findings to scientific studies. Students also need to communicate and defend their findings (NRC, 1996; Achieve, 2013). A science writing heuristic attempts to be a reflection of the interactive dialog and meaning-making that occurs in the scientific community. Emphasis is on communication of claims made and how they compare with current scientific understandings (Hand, et al, 2004).

This study has given limited evidence that using a science writing heuristic could be a beneficial instructional practice for improving students’ motivation to learn science. It has also shown in this study to increase the students’ sense of self-efficacy to engage in science. Females in particular faired well from participating in this writing-to-learn strategy. Their increase in both Achievement and Performance Goal scores indicate that they experienced an increase in both intrinsic and extrinsic motivation to learn science after participating in a SWH for a semester. Their increase in the Science Learning Value score indicates their understanding of the value of science in their everyday lives. Females’ increase in understanding the value of science, intrinsic, and extrinsic motivation to learn science could have positive impacts related to their persisting in science learning and increasing their science achievement. Not all science concepts are likely to be intrinsically motivating to students and the desire to be perceived as competent in science and to be liked by the teacher may sustain female students in engaging science learning during those times (DeBacker & Nelson, 2000; Eccles, J., 1983).

In light of the science achievement gap that exists between males and females and fewer females entering STEM careers than males, effective teaching strategies that engage,
interest, and motivate females in science subjects could have a positive impact on more females entering and persisting in science (Bacharach, Baumeister, & Furr, 2003; Brotman & Moore, 2008; Ma, 2008; Henman, 2013).

Future studies of interest include looking at the effects of using SWH over longer periods of instruction, perhaps an entire course. Looking at the effects of SWH on motivation to learn science between students of different ethnicities and socioeconomic status. Research over the use of SWH by a professional learning community could provide valuable information on the needed and provided supports and the varying levels of comfort and implementation.
References

Achieve, Inc. on behalf of the twenty-six states and partners that collaborated on the NGSS (2013). *Next Generation Science Standards*. Achieve, Inc. on behalf of the twenty-six states and partners that collaborated on the NGSS. Available: www.nextgenscience.org


