Examining the use of the Science Writing Heuristic on gender and achievement groups in a high school biology classroom

Sarah Elizabeth Trosper
Iowa State University

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Examining the use of the Science Writing Heuristic on gender and achievement groups in a high school biology classroom

by

Sarah Elizabeth Trosper

A thesis submitted to the graduate faculty in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Major: Education

Program of Study Committee:
Brian Hand (Major Professor)
Jim Colbert
Joanne Olson

Iowa State University

Ames, Iowa

2004
Graduate College
Iowa State University

This is to certify that the master's thesis of

Sarah Elizabeth Trosper

has met the thesis requirements of Iowa State University

Signatures have been redacted for privacy
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CHAPTER 1. GENERAL INTRODUCTION

Purpose of Study

Student writing in science is one way for teachers to gain an understanding of students' prior knowledge and what they have learned throughout the course of a unit of study. Writing-to-learn in science (Bereiter & Scardamalia, 1987) has been shown to be effective in helping students gain a cognitive understanding of the process of science and scientific ideas. This study was designed to determine whether student writing, after completing restructured curricular activities, has an effect on overall learning. During this study students will be introduced to the science writing heuristic (Keys, Hand, Prain, & Collins, 1999) and restructured science activities in the regular biology curriculum.

Background of Research Topic

The National Science Foundation has supported the development of the National Science Education Standards (National Research Council, 1996) in response to concern raised regarding pre-college science courses and declining student performance in the United States in the area of science over the past several decades. The National Research Council has strongly recommended a science curriculum that focuses on broad scientific concepts rather than long sets of facts concerning a particular topic. One of the specific problems addressed by these national standards was that secondary science historically has been taught (primarily) through lecture with emphasis on long lists of trivial facts and vocabulary words (Champagne & Hornig, 1987).

The NRC has aided science curriculum developers in choosing content that covers the most important science concepts without emphasizing long lists of trivial information. The NRC also recommends that science curricula devote significantly more time to developing
scientific thinking skills and understanding the nature of science through engaged student investigation. Activities based on the national standards stress student thinking, decision-making, inquiry, collaboration and communication.

The way in which students learn and process scientific concepts and ideas can be approached from a variety of learning theories. This study will be structured around the constructivist learning theory. The constructivist learning theory (Driver & Oldham, 1986; Simon, 1995) is based on the idea that students construct their knowledge from prior experiences through classroom activities and novel experiences. This method of constructing knowledge can be related to the way in which scientists construct theories and laws in science. The way in which students construct this knowledge is one focus of curriculum development in science education (Driver & Oldham, 1986).

One writing task that has been proposed to promote learning from laboratory activities in science is the science writing heuristic (SWH) (Keys, et al., 1999). The SWH is composed of two templates; both student and teacher, to aid in structuring writing activities during laboratory investigations. This writing heuristic has moved away from using writing in science to demonstrate understandings toward aiding students in constructing knowledge regarding scientific concepts and ideas.

The SWH has been used in several studies (Hand, Prain, and Wallace, 2002; Keys, et al., 1999) and has been shown to be effective in the secondary science classroom. The SWH is still a fairly new approach to laboratory investigations and takes a great deal more time to complete than the traditional approach. However, the results may be a greater conceptual understanding of science concepts and an understanding of how scientists conduct investigations in the real world setting.
Research Questions

Three research questions are the focus of this study for each unit.

Cell Unit
- Does student writing through using the SWH and restructured science activities lead to higher conceptual understanding of cells in one gender when compared to the other?
- Does student writing through using the SWH and restructured science activities lead to higher conceptual understanding of cells in one achievement group over another?
- Does student improvement at the end of the cells unit differ by gender or achievement level?

Genetics Unit
- Does student writing through using the SWH and restructured science activities lead to higher conceptual understanding of genetics in one gender when compared to the other?
- Does student writing through using the SWH and restructured science activities lead to higher conceptual understanding of genetics in one achievement group over another?
- Does student improvement at the end of the genetics unit differ by gender or achievement level?

Organization of Thesis

This paper presents a study based on the constructivist learning theory and the implementation of non-traditional writing in a high school biology classroom. A study was
designed to measure the benefits of using the science writing heuristic (SWH) on higher conceptual understanding of two topics, cells and genetics. There are four main sections:

**Literature Review**

The literature review presents a rationale for the research study. It is broken down into three sections. The first section outlines the constructivist learning theory. It provides a detailed description of how students learn by adding new information to existing frameworks through assimilation or completely changing existing frameworks through accommodation. The process of accommodation is described by the conceptual change model (CCM). A detailed explanation of the model is described in chapter 2.

The second section of the literature review focuses on writing-to-learn in science through using a method called the science writing heuristic (SWH). The SWH was introduced to encourage a higher conceptual understanding during science laboratories and activities. It encourages student investigation of problems by collecting evidence to make claims and negotiate meaning. The SWH has two templates, the teacher and the student. Both are described in detail in chapter 2. Previous research in the area of gender and achievement in science is presented to provide a background for the research questions of the study. Traditionally, males have been more successful in the area of science, however, the gap appears smaller in biological sciences.

The final section emphasizes the importance of teacher behaviors in a constructivist learning environment while using the SWH. They are vastly different from a traditional science classroom. Important teacher behaviors and strategies such as questioning, wait time, non-verbals and responding are introduced. The importance of these behaviors is stressed for successful implementation of the SWH.
Materials and Methods

The second section of this paper presents the design and setting of the research project. A detailed description of the two curricular units involved in the study, cells and genetics, is presented along with the three major concepts for each unit. Data sources for the study include a baseline test used to determine achievement level, a unit test taken before the study began used as a covariate, and pre and post tests for the two units. A detailed description of all variables involved in the study is presented in this chapter.

Pre-test and improvement scores were analyzed using one-way analysis of variance (ANOVA) and post-test scores were analyzed using analysis of covariance (ANCOVA).

Results

The third section of this paper presents the statistical results of the research study. The results are broken down into the two units studied: cells and genetics. Each unit is presented with results for gender, achievement level, and improvement scores. Three areas of student performance are presented: multiple-choice question totals, conceptual question totals and total test scores.

Discussion, Limitations, and Implications

The final section of the paper ties together material presented in the literature review with the statistical results from the study. Trends and patterns of multiple-choice question totals, conceptual question totals and total test scores for the two units are discussed by answering the six research questions. This is followed by an exploration of limitations of the study. Finally, implications for future use and research of the science writing heuristic are presented.
CHAPTER 2. LITERATURE REVIEW

Traditionally, most of the writing in science has been done while taking notes and writing research papers, completing lab and homework assignments, and occasionally writing a research paper on a specified topic. Creative or instructional writing has not really been proposed as part of the science curriculum until recently. Research being done in the area of writing for a better understanding of science concepts has shown that this process can be very beneficial and rewarding for both students and teachers (Keys, et al., 1999).

The Constructivist Learning Theory

The constructivist learning theory has been the focus of many education reform movements here in the United States and around the world. Countless studies have been done to address the notion that learners actively construct knowledge from prior experience to build a framework for understanding an idea or concept (Driver & Oldham, 1986; Simon, 1995).

"We construct our knowledge of our world from our perceptions and experience, which are themselves mediated through our previous knowledge. Learning is the process by which human beings adapt to their experiential world." (Simon, 1995, p. 115)

As people learn, they attempt to make sense of the ideas and concepts they encounter. Constructivist learning does not focus on the acquiring of "bits" of factual information by the learner, rather the overall framework for understanding. Learning is an active process, not a passive one. "Learning is an active construction of meaning. These constructions are seen as tentative models, which are constantly tested against experience and if necessary modified." (Driver & Oldham, 1996)
The learner can process new ideas in two ways. They can be added to existing framework through the process of assimilation, or completely change an existing framework through the process of accommodation (Henriques, 1997; Posner, Strike, Hewson, & Gertog, 1982; Thorley & Stofflett, 1996). Henriques (1997) notes that assimilation can be referred to as conceptual growth while accommodation as conceptual change.

Assimilation takes place when a learner can add existing ideas to a larger concept already in place. For example, adding branches to a tree or ice fishing to existing fishing experiences. The learner is not changing his or her “big ideas,” rather adding experiences to them.

Accommodation is a much more complicated process. It is a process that occurs over time and is different for all individuals. In order for conceptual change to occur, a new idea must be presented to the learner that does not fit into his or her existing framework. This must cause dissatisfaction to entice the learner to begin the process of constructing a new understanding of a concept. This is a very important step in the process of conceptual change. If a learner finds nothing wrong with the ideas and concepts presented, he or she will simply add these ideas to the existing framework and conceptual growth will occur.

This view is outline in the conceptual change model (CCM) (Stephans, 1994; Thorley & Stofflett, 1996). The CCM model is very similar to the learning cycle, which includes 3 stages: exploration, concept invention, and application. The CCM acknowledges the value of the learning cycle, but goes beyond the three stages. The CCM has two major components: a set of conditions explained in the next paragraph and conceptual ecology (the environment in which the learner learns.)
Once a learner is dissatisfied with an idea, he or she must find the new idea intelligible, plausible, fruitful, and feasible for conceptual change to occur (Posner et al., 1982; Thorley & Stofflet, 1996). In order to find an idea intelligible, it must make sense in a logical argument. Learners must be able to see an initial meaning in a new concept. Second, the learner must find the idea plausible (reasonable). It must at least have the capability to solve a problem. Third, the idea must be fruitful. It must be able to be applied to more than one problem for the learner. The final requirement for conceptual change is feasibility. The new idea finally replaces the old idea to solve a wide range of problems for the learner. Conceptual ecology ties in other cognitive factors such as other knowledge, past experiences, and epistemological commitments to the learner (Thorley & Stofflet, 1996).

Approaches to Constructivist Learning

Constructivist learning can be interpreted in a variety of ways. The three main perspectives to constructivism are radical, interactive, and social (Henriques, 1997). In radical constructivism, learning is seen as a completely individual process. On the other hand, social constructivism is seen as a completely social process. This study focused around the third approach, interactive constructivism. In this approach, students construct knowledge when they are able to interact with others, but create meaning for themselves when they have time to reflect and make sense of those interactions. For practical purposes, teachers need to acknowledge that students learn on both public and private terms. The only person that have control over learning is the learner. The teacher can facilitate that learning in the classroom, and the most logical way to do that is to create an environment where both public and private learning can take place.
Writing-to-Learn

Klein (1999) notes that "writing may help students to think critically and to construct new knowledge" (p. 204). In this concept of writing-to-learn, students are able to explore the relationships between ideas, specifically in the area of science. However, when looking at writing as an instructional tool, Bereiter and Scardamalia (1987) distinguish between knowledge telling and knowledge transforming. When knowledge telling, students are simply retrieving ideas already stored in memory and putting them down on paper. This is common on short answer assessments when students are asked to recall information and write it down word for word to answer a question. On the other hand, knowledge transforming allows students to make new connections and "construct" knowledge through active problem solving. This type of writing involves a two-way interaction between content space, where content is stored, and rhetoric space, where the goals for the text are worked out. As writers move back and forth between these two spaces, their understandings of the topics are further developed. This is demonstrated on higher-order essay questions when students are asked to apply concepts they have learned to a new situation.

The Science Writing Heuristic

Hand, Prain, Lawrence and Yore (1999) view science as the construction of persuasive explanations about the natural world. As scientists explore the natural world and find new evidence to support existing or new concepts, they must be able to explain these findings to their peers and the public. One way this is done is through the process of writing. "If students are to understand science as the construction of persuasive but ultimately provisional explanations of the natural world, then they will need to tackle writing tasks that
enable them to understand and practice this kind of inquiry, its procedures, and basis.”

(Hand, et al., 1999, p. 1,024)

The SWH requires a much different teacher approach to laboratory investigations. The teacher’s role in the SWH is to provide activities that involve “meaningful student thinking, writing, reading and discussion about laboratory activities” (Keys, et al., 1999, p. 1,067). Before beginning an investigation, the teacher needs to gain an understanding of the students’ prior knowledge within a topic. This can be done through a simple pre-test or concept mapping. Once this prior knowledge has been established, the teacher may then move forward when planning laboratory activities. These activities are much less teacher directed and much more student-centered. Students are actively involved in making decisions within the laboratory activity and are not necessarily required to arrive at the same final answer. Once the actual investigation has been completed, students are led through four negotiation phases using different types of writing (journals, charts, answering focus questions, and poster presentations) while collaborating with their peers. Initially, students construct their own meanings as to why something happened in an experiment through investigation and observation. Toward the end of the experiment students are able to collaborate with each other to share and refine ideas through engaging in discussion and consulting other sources of information (textbooks, internet, etc.).

Figure 1. The Science Writing Heuristic, Part 1: A template for teacher-designed activities to promote laboratory understanding.

1. Exploration of pre-instruction understanding through individual or group concept mapping.
2. Pre-laboratory activities, including informal writing, making observations, brainstorming, and posing questions.
3. Participation in laboratory activity.
Figure 1. The Science Writing Heuristic, Part I (cont.)

4. Negotiation phase I – writing personal meanings for laboratory activity. (For example, writing journals.)
5. Negotiation phase II – sharing and comparing data interpretations in small groups. (For example, making group charts.)
6. Negotiation phase III – comparing science ideas to textbooks or other printed sources. (For example, writing group notes in response to focus questions.)
7. Negotiation phase IV – individual reflection and writing. (For example, creating a presentation such as a poster or report for a larger audience.)
8. Exploration of post-instruction understanding through concept mapping.

The student template for the SWH is very basic, but may be altered to fit specific activities or investigations. Students begin their investigations by brainstorming questions and ideas in an attempt to solve the problems posed to them by their teacher or peers. This may take the investigation on a variety of different paths and will require flexibility by the teacher within the classroom. Once students have chosen the path they will use to test their ideas, they move on to making observations and claims using evidence collected within the investigation. Once this phase is complete, students then work through the negotiation phases, comparing their ideas to others, and reflecting on how their ideas have changed throughout the investigation.

Figure 2. The Science Writing Heuristic, Part II: A template for student thinking.

1. Beginning ideas – What are my questions?
2. Tests – What did I do?
3. Observations – What did I see?
4. Claims – What can I claim?
5. Evidence – How do I know? Why am I making these claims?
6. Reading – How do my ideas compare with other ideas?
7. Reflection – How have my ideas changed?
The SWH has been used in several studies (Hand, et al., 2002; Keys, et al., 1999) and early results have shown that both discussion and writing have led to conceptual change in students.

Gender

One area of particular concern in science is the fact that boys have traditionally outperformed girls in science achievement measures. Female students have even tended to avoid science courses or drop out after experiencing repeated failures (Rivard, 1994). However, these differences have not been consistent across all science areas. Boys tend to do better in the physical sciences while the differences between boys and girls in the biological sciences is relatively minimal (Levin, Sabar, & Libman, 1991).

Lower parental expectations of females in science courses, the lack of opportunity to experience science in the "real world" setting, and cultural stereotyping of female roles are all mentioned as possible factors in low female achievement in the area of science (Levin, et al., 1991). These factors may lead to lack of effort, low self-confidence and low interest for females in science courses.

Educators have suggested particular learning and teaching strategies to make the science classroom more gender-inclusive. These ideas include the sharing of ideas, classroom dialogue, peer discussion, journal activities, and concrete science experiences (Rivard & Straw, 2000). One national survey has even shown that females like to write more than males, so the writing-to-learn strategies may be effective teaching and learning strategies for this group of students (Rivard, 1994).
Achievement Level

Achievement level differences in science have not been a large area of research. In one study performed by Rivard & Straw (2000) they found that “students of low and average ability who used talk, either alone or combined with writing, appear to have learned more initially, while also showing better retention of this knowledge over time” (p. 585). On the other hand, the high-ability students in the same study appeared to do better when they individually wrote in response to the task at hand.

Another specific area mentioned in the literature regarding achievement levels in science are the low-achieving females. Some of their low-achievement was possibly attributed to low expectations from parents, teachers and themselves (Levin et al., 1991).

The Teacher’s Role

The majority of current teachers in classrooms today were taught in traditional settings where the teacher is seen as the “gatekeeper” of information. Specifically, science is viewed as a rigid body of facts, theories, and rules to be memorized (Van Driel, Beijaard, & Verloop, 2001). The role of the teacher in traditional instruction is to “give” information to the students. The students’ role is to acquire that information and to regurgitate it back to the teacher on assessments. The classroom is viewed as an orderly environment where students are all working on the same assignment in a similar fashion (Hunter, 1984).

In a constructivist classroom, teacher behaviors are used to encourage student exploration of concepts that have caused them dissatisfaction. Students don’t just construct this new knowledge on their own; they need to be presented with ideas that constantly challenge their existing frameworks.
Teacher Behaviors

In a traditional learning environment, teachers are asked to make the classroom exciting rather than boring, make material interesting so students want to learn, reinforce students in their learning and make material relate to real life experiences of the learner (Hunter, 1984). In the constructivist classroom while using the SWH, teacher behaviors are used to encourage student exploration of concepts that have caused them dissatisfaction. Students don’t just construct this new knowledge on their own; they need to be presented with ideas that constantly challenge their existing frameworks. This can be accomplished through effective teacher questioning, wait time, non-verbals and responses. The use of these strategies is critical to the success of SWH activities.

Questioning

Questions are a part of classroom interactions between students and teachers every day. Unfortunately, most questions asked in the classroom are designed to determine whether or not a student knows a particular item of information (cognitive memory recall) (Blosser, 1990). These data recall questions tend to put students on the spot, make them uncomfortable, and give the teacher nothing to build from in a class discussion or activity.

Knowing when and how to ask the “right” questions is a very important step in moving toward a constructivist classroom setting. Penick, Crow, & Bonnstetter (1996) have developed a simple mnemonic to remember the logical order for categories of questions: H (History) R (Relationships) A (Application) S (Speculation) E (Exploration). These questions are designed to help teachers understand what students think to be able to put them in situations where the concepts can be demonstrated, talked about and explored. Initially, the “history” questions help determine what misconceptions or alternative frameworks students
have about a particular topic. These misconceptions help frame the direction the activities will take throughout the unit of study.

The questions are designed to be clear and non-threatening for the student. Questions such as "What did you do?, What procedure did you use?, What made you think of doing that?" (Penick et al., 1996) are designed to allow students to elaborate, in their own terms, what steps they went through to carry out an experiment. They are also devised to be higher-level thinking questions, which require more than just a simple yes or no answer (Blosser, 1990; Penick et al., 1996). As they move through the mnemonic, students are able to reflect on their decisions, make connections with prior experiences, make predictions for future experiments, and communicate their ideas and results to others.

**Wait Time**

If students are expected to construct knowledge through classroom experiences, they need time to reflect on the information and ideas being addressed. This time is referred to as wait time (Clark et al., 2000; Rowe, 1990). Wait time is divided into two areas; wait time I and wait time II (Blosser, 1990). Wait time I involves the silent time after the teacher asks an initial question. Rowe (1990) mentions that in most classrooms teachers typically wait less than a second for a student response once a question is asked. Wait time II is the silent time after the initial student response to give that student (or another student in the classroom) time to add to, modify, or elaborate on the response. Often times, teachers cut off student elaborations. This causes students to feel uncomfortable and less likely to answer questions in the future.

It is suggested that a teacher should wait three to five seconds before rephrasing a question or moving on to another question (Rowe, 1990). Studies have shown that increased
wait time has had significant impacts on student achievement and interactions in the classroom. From a constructivist perspective, increased wait time results in more inferences being supported by evidence and logical argument and student-to-student exchanges increase.

**Non-Verbals**

Non-verbals can be used very effectively in the classroom to get students’ attention without saying anything at all. Non-verbals are teacher behaviors that do not require talking. Examples of non-verbals included gestures, eye contact, raising eyebrows, facial expressions, proximity, location in the classroom, and many more. Non-verbals play a very important role in questioning and wait time (Clark et al., 2000). They are an effective way to let the students know you are very interested in what they are doing and thinking without saying a word. Non-verbals can be used during questioning to elicit student misunderstandings and encourage student-to-student conversation.

**Responding**

Responding to student questions is a natural instinct for teachers. However, too often, teachers respond with praise or correct answers instead of questions to encourage student exploration (Sadker & Sadker, 1985). Praise in the classroom certainly has its place, but it needs to be used at the right time and place to become effective. Often times, students rely on praise to feel as if they are on the right path in their experiments. This may have a negative effect on the student because it causes them to feel as if what they have done is adequate.

Providing student feedback continues to be one of the most important roles of the teacher. Research has suggested that specific feedback from the teacher is important for student achievement (Blosser, 1990). This feedback can most effectively come in the form of
questions, which ask students to further explain ideas and clarify responses. These questions can help students construct knowledge, both privately and socially, using their own interpretations or ideas from their classmates.
CHAPTER 3. MATERIALS AND METHODS

This research study was designed around the use of the science writing heuristic (SWH) in a high school biology classroom. The writing heuristic was implemented during two units of study, cells and genetics. Data collected during the study was analyzed using quantitative research methods. One-way analysis of variance (ANOVA) and analysis of covariance (ANCOVA) were chosen as the statistical methods for the data set.

Research Design

Research from this study was collected in a high school biology classroom during two units of study: cells and genetics. Three major concepts were the focus of the study for each unit. Activities and laboratories were structured to focus on and reinforce concepts using the science writing heuristic (SWH). The study was completed between October 2003 and January 2004.

Setting

The target population for this study were high school students, grades 9-12, enrolled in a general high school biology course. During the first unit on cells, 113 students were involved in the study and that number dropped slightly to 102 students for the second unit on genetics. The drop in number for the second unit is due to student attrition and transfers out of the school. The study was conducted in a high school in Central Iowa with a population of approximately 2,000 students.

Table 1. Gender of Students in the Study

<table>
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<th>Genetics Unit</th>
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<td>50</td>
<td>44</td>
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<td>Female</td>
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Organization of Curricular Units

Before the first unit of the study was introduced, students completed a murder mystery activity to be introduced to the notion of claims and evidence in scientific investigations. Students were given a scenario where a murder had occurred and they had limited information to determine the culprit. Once students had an opportunity to make claims and provide evidence in a class discussion, new information was introduced the following day.

Cells

Three big ideas were the focus of the study in each unit. The unit on cells addressed the following major concepts:

1. The structure and function of cells
2. The various types of cells
3. Cellular transport

During this unit, six activities were introduced to students using the science writing heuristic. The six SWH activities included in the cells unit were: the cheek cell lab, the onion cell lab, the food coloring activity, the dialysis tubing activity, the egg lab and the fish activity. The cheek cell lab provided students an opportunity to observe their own epithelial cells under the microscope and to try and identify structures in the cells. The onion cell lab was very similar to the cheek cell lab, but provided a different type of cell for students to observe and make comparisons with the epithelial cells. The food coloring activity introduced the idea of diffusion to the students using different temperatures of water and food coloring. The dialysis tubing, fish activity, and egg lab provided opportunities for students to observe materials moving through membranes from one concentration to another. During these activities
students were not introduced to specific biology vocabulary terms until after they had completed writing activities for each activity.

**Genetics**

The unit on genetics covered the following major concepts:

1. Mendel’s studies of inheritance and probability
2. Protein assembly in cells
3. Genetic traits and diseases passed down from parents to offspring

During the second unit, 2 activities were completed by students using the SWH: the banana lab and the Duchenne Muscular Dystrophy activity. In the banana lab, students had the opportunity to extract DNA from a banana. Students had to interpret a family pedigree in the Duchenne Muscular Dystrophy activity to determine the chances of the offspring receiving the MD gene.

**Data Sources**

Data from the study consisted of a baseline test over general science concepts given to students at the beginning of the semester, a unit test given to all participants after the first unit of study but before the study began, and pre and post instructional tests using both multiple-choice and conceptual questions for the two units of study. The baseline test scores were used to determine achievement levels (low, medium and high) in the study. The total scores on the baseline test were split into thirds, with approximately the lower one-third representing the low-achievement group, the middle one-third representing the medium-achievement group, and the upper one-third representing the high-achievement group. The unit 1 test given to students after the first unit of study in biology but before the study began was used as the covariate. At the beginning of each unit of study, students were given a pre-
test to assess their prior knowledge within the specific topic to be studied. The pre-test consisted of 10 multiple-choice questions and 4 essay questions. The pre-tests were written using samples from the advanced placement biology test for the essay questions and a biology exam generator for the multiple-choice questions. The exam generator is a database of biology questions which can be used to aid teachers in developing tests. All students were given an equal amount of time to complete the tests and the tests were graded using a rubric to ensure consistency in grading. After completing the laboratory assignments in the units of study (approximately 4-5 weeks for each unit), students were given the post instruction test. This was the same measurement that was used as the pre-test before the unit began. All student scores on pre and post tests were converted into percentages for comparison in the study.

Variables

For each unit of study, six dependent variables—pre-test multiple choice total, pre-test conceptual question total, pre-test total, post-test multiple choice total, post-test conceptual question total, and post-test total, two independent variables—gender and ability level, and one covariate—unit one test—were used in the data analysis.

Table 2. Detailed Explanation of Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-test Multiple-choice total</td>
<td>Multiple-choice questions score on the pre-test translated into percentages.</td>
</tr>
<tr>
<td>Pre-test Conceptual Questions total</td>
<td>Conceptual questions score on the pre-test translated into percentages.</td>
</tr>
<tr>
<td>Pre-test total</td>
<td>The sums of the percentages of multiple-choice and essay questions scores for the pre-test.</td>
</tr>
<tr>
<td>Post-test Multiple-choice total</td>
<td>Multiple-choice questions score on the post-test translated into percentages.</td>
</tr>
<tr>
<td>Post-test conceptual Questions total</td>
<td>Conceptual questions score on the post-test translated into percentages.</td>
</tr>
</tbody>
</table>
Table 2. Detailed Explanation of Variables (cont.)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Post-test total</td>
<td>The sums of the percentages of multiple-choice and essay questions scores for the post-test.</td>
</tr>
<tr>
<td>Gender</td>
<td>Gender of the participants in the study (male and female).</td>
</tr>
<tr>
<td>Achievement Level</td>
<td>Calculated using the baseline test scores over general science material divided into thirds, the bottom one-third representing the low-achievement students, the middle one-third representing the middle achievement students and the upper one-third representing the high achievement students.</td>
</tr>
<tr>
<td>Unit One Test</td>
<td>Used as the covariate in the ANCOVA for each post-test unit result.</td>
</tr>
</tbody>
</table>

**Method of Analysis**

One-way analysis of variance (ANOVA) was used to test the significance of group differences between two or more means as it analyzes variation between and within each group. One-way ANOVA was used to measure differences between gender (male and female) and achievement groups (low, medium, and high) in both cell and genetics pre-tests and test improvement scores for both units. Data for a one-way ANOVA was reported using means and standard errors. However, when more than one independent variable is involved in a study (i.e. gender and ability level), it is difficult to determine which variable may have had an effect on the dependent variable (Mertler & Vannatta, 2002).

Using analysis of covariance (ANCOVA) allows researchers to more appropriately analyze data collected in social science setting. A covariate was used to adjust scores on the dependent variable and reflect initial differences on the covariate. For this study, main effects and interactions between gender and achievement level were assessed after the effects of the unit one test (the covariate) were removed. Analysis of covariance was used to determine differences in cell and genetics post-test results. ANCOVA results were reported using adjusted means and standard deviations. Statistically significant results were reported when p < .05 for both ANOVA and ANCOVA results.
CHAPTER 4. RESULTS

Results are broken down into the two units in which the study focused, cells and genetics. Within each unit, statistical results comparing both gender and achievement level are presented using pre-test data, post-test data, and improvement scores. One-way ANOVA results are presented using mean scores and standard deviations. Analysis of covariance (ANCOVA) results are presented using adjusted mean scores, due to the covariate, and standard errors.

Cell Unit

Gender

A one-way ANOVA was used to determine differences between male and female students for pre-test multiple choice questions, pre-test conceptual questions, and pre-test total before the unit on cells began. One-way ANOVA results (see table 3) indicated significant differences between groups (males vs. females) on multiple-choice question totals \(F(1,109) = 3.921, p = .050\), but no significance existed on conceptual questions \(F(1,109) = .416, p = .520\) or pre-test total scores \(F(1,109) = 1.947, p = .166\). In all three areas, males scored higher than females on the cell pre-test.

Table 3. Cell Unit Pre-Test Means and Standard Deviations for Males and Females

<table>
<thead>
<tr>
<th></th>
<th>Gender</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>%Pre-test Conceptual</td>
<td>Male</td>
<td>48</td>
<td>4.6007</td>
<td>6.24199</td>
</tr>
<tr>
<td>Questions Total</td>
<td>Female</td>
<td>63</td>
<td>3.8690</td>
<td>5.66057</td>
</tr>
<tr>
<td>%Pre-test Multiple-choice</td>
<td>Male</td>
<td>48</td>
<td>37.0833</td>
<td>17.25384</td>
</tr>
<tr>
<td>Questions Total</td>
<td>Female</td>
<td>63</td>
<td>31.1111</td>
<td>14.49261</td>
</tr>
<tr>
<td>%Pre-test Total</td>
<td>Male</td>
<td>48</td>
<td>10.2011</td>
<td>6.77472</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>63</td>
<td>8.5660</td>
<td>5.56508</td>
</tr>
</tbody>
</table>
A 2x3 analysis of covariance (ANCOVA) was conducted for the cell unit to determine the effect of gender (male vs. female) and achievement levels (low, medium, and high) on post-test multiple-choice questions, post-test conceptual questions and post-test totals when controlling for unit 1 test scores. ANCOVA results for gender (see table 4) indicated no significant main effects on multiple-choice questions ($F(1,106) = .909, p = .342, \text{partial } \eta^2 = .009$), conceptual questions ($F(1,106) = 1.684, p = .197, \text{partial } \eta^2 = .016$), or total test questions ($F(1,106) = .943, p = .334, \text{partial } \eta^2 = .009$). Males scored higher than females on multiple-choice questions, but females outscored males on conceptual questions and the total test.

Table 4. Cell Unit Post-Test Adjusted Means and Standard Error for Males and Females

<table>
<thead>
<tr>
<th>%Post-test Conceptual Questions Total</th>
<th>Gender</th>
<th>N</th>
<th>Adj. Mean</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>%Post-test Multiple-choice Questions Total</td>
<td>Male</td>
<td>50</td>
<td>27.751</td>
<td>2.761</td>
</tr>
<tr>
<td>%Post-test Total</td>
<td>Female</td>
<td>63</td>
<td>32.437</td>
<td>2.333</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>%Post-test Multiple-choice Questions Total</th>
<th>Gender</th>
<th>N</th>
<th>Adj. Mean</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>%Post-test Total</td>
<td>Male</td>
<td>50</td>
<td>64.970</td>
<td>3.001</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>63</td>
<td>61.227</td>
<td>2.536</td>
</tr>
</tbody>
</table>

Achievement Level

A one-way ANOVA was used to determine differences between achievement levels (low, medium, and high) for pre-test multiple choice questions, pre-test conceptual questions, and cell pre-test total scores. One-way ANOVA results (see table 5) indicated significant differences between groups (low, medium, and high) on both multiple-choice questions ($F(2, 108) = 5.962, p = .003$) and pre-test totals ($F(2, 108) = 4.384, p = .015$), but no significance existed on conceptual question totals ($F(2,108) = 1.625, p = .202$). Ability levels (low,
medium, and high) were consistent with results from the mean pre-test scores in all three areas.

Table 5. Cell Unit Pre-Test Means and Standard Deviations for Achievement Level

<table>
<thead>
<tr>
<th>Achievement Level</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>%Pre-test Conceptual</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Questions Total Low</td>
<td>34</td>
<td>3.1250</td>
<td>4.47854</td>
</tr>
<tr>
<td>Medium</td>
<td>33</td>
<td>3.6616</td>
<td>5.61028</td>
</tr>
<tr>
<td>High</td>
<td>44</td>
<td>5.3977</td>
<td>6.90698</td>
</tr>
<tr>
<td>%Pre-test Multiple-Choice</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Questions Total Low</td>
<td>34</td>
<td>27.0588</td>
<td>12.43880</td>
</tr>
<tr>
<td>Medium</td>
<td>33</td>
<td>33.3333</td>
<td>15.94261</td>
</tr>
<tr>
<td>High</td>
<td>44</td>
<td>39.0909</td>
<td>16.68005</td>
</tr>
<tr>
<td>%Pre-test Total</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>34</td>
<td>7.2515</td>
<td>4.46745</td>
</tr>
<tr>
<td>Medium</td>
<td>33</td>
<td>8.7774</td>
<td>5.64250</td>
</tr>
<tr>
<td>High</td>
<td>44</td>
<td>11.2069</td>
<td>7.08933</td>
</tr>
</tbody>
</table>

ANCOVA results for achievement level (see table 6) indicated no significant main effects on multiple-choice questions (F (2,106) = 1.864, p = .160, partial \( \eta^2 = .034 \)), conceptual questions (F (2,106) = 1.176, p = .312, partial \( \eta^2 = .022 \)) or total test scores (F (2,106) = 1.564, p = .214, partial \( \eta^2 = .029 \)). In all three areas, the low achievement level group scored higher than the medium achievement level group.
Table 6. Cell Unit Post-Test Adjusted Means and Standard Errors for Achievement Level

<table>
<thead>
<tr>
<th>Achievement Level</th>
<th>N</th>
<th>Adj. Mean</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>%Post-test Conceptual</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Questions Total</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>35</td>
<td>30.180</td>
<td>3.354</td>
</tr>
<tr>
<td>Medium</td>
<td>33</td>
<td>26.657</td>
<td>3.349</td>
</tr>
<tr>
<td>High</td>
<td>45</td>
<td>33.446</td>
<td>2.857</td>
</tr>
<tr>
<td>%Post-test Multiple-choice</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Questions Total</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>35</td>
<td>62.953</td>
<td>3.646</td>
</tr>
<tr>
<td>Medium</td>
<td>33</td>
<td>58.536</td>
<td>3.640</td>
</tr>
<tr>
<td>High</td>
<td>45</td>
<td>67.807</td>
<td>3.106</td>
</tr>
<tr>
<td>%Post-test Total</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>35</td>
<td>35.830</td>
<td>3.093</td>
</tr>
<tr>
<td>Medium</td>
<td>33</td>
<td>32.153</td>
<td>3.088</td>
</tr>
<tr>
<td>High</td>
<td>45</td>
<td>39.370</td>
<td>2.635</td>
</tr>
</tbody>
</table>

Improvement Scores

A one-way ANOVA was used to measure improvement scores for the cell unit between pre-test and post-test scores for both gender and achievement level. The ANOVA results (see table 7) indicated no significant results in improvement scores between males and females on multiple-choice question totals (F (1,107) = .781, p = .379), conceptual question totals (F (1,107) = .169, p = .682) or total test score (F (1,107) = .085, p = .772). In both conceptual questions and total test scores, females improved slightly more than males. However, males improved slightly more than females on multiple-choice questions.

Table 7. Cell Unit Improvement Means and Standard Deviations for Males and Females

<table>
<thead>
<tr>
<th></th>
<th>Gender</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conceptual</td>
<td>Male</td>
<td>47</td>
<td>.2685</td>
<td>.19979</td>
</tr>
<tr>
<td>Questions Total</td>
<td>Female</td>
<td>62</td>
<td>.2863</td>
<td>.23940</td>
</tr>
<tr>
<td>Multiple-choice</td>
<td>Male</td>
<td>47</td>
<td>.4687</td>
<td>.32130</td>
</tr>
<tr>
<td>Questions Total</td>
<td>Female</td>
<td>62</td>
<td>.4117</td>
<td>.34180</td>
</tr>
<tr>
<td>Total Test</td>
<td>Male</td>
<td>47</td>
<td>.2933</td>
<td>.20095</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>62</td>
<td>.3057</td>
<td>.23157</td>
</tr>
</tbody>
</table>
When comparing achievement level improvement (see table 8), significant differences occurred in both conceptual question totals \(F(2,106) = 3.799, p = .025\) and total test scores \(F(2,106) = 3.871, p = .024\). No significant differences were found in multiple-choice question totals \(F(2,106) = 2.401, p = .096\). In all three areas tested, the low achievement group improved more than the medium achievement group. The high level group improved the most on all three areas tested.

<table>
<thead>
<tr>
<th>Improvement Scores</th>
<th>Achievement Level</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conceptual Questions Total</td>
<td>Low</td>
<td>33</td>
<td>.2321</td>
<td>.21955</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>32</td>
<td>.2310</td>
<td>.20708</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>44</td>
<td>.3482</td>
<td>.22161</td>
</tr>
<tr>
<td>Multiple-Choice Questions Total</td>
<td>Low</td>
<td>33</td>
<td>.4539</td>
<td>.27057</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>32</td>
<td>.3332</td>
<td>.35554</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>44</td>
<td>.4981</td>
<td>.34715</td>
</tr>
<tr>
<td>Total Test</td>
<td>Low</td>
<td>33</td>
<td>.2639</td>
<td>.20640</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>32</td>
<td>.2441</td>
<td>.20802</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>44</td>
<td>.3685</td>
<td>.21986</td>
</tr>
</tbody>
</table>

**Genetics Unit**

A one-way ANOVA was used to determine differences between male and female students for pre-test multiple choice questions, pre-test conceptual questions, and pre-test total prior to the unit on genetics. One-way ANOVA results (see table 9) indicated no significant differences between groups (males vs. females) on multiple-choice questions \(F(1,100) = .196, p = .659\), conceptual questions \(F(1,100) = 2.538, p = .114\), or pre-test total \(F(1,100) = .923, p = .339\). One thing to note at the start of the second unit of study is that
females were now scoring higher on conceptual questions and the total test while males were still scoring higher on multiple choice questions.

Table 9. Genetics Unit Pre-Test Means and Standard Deviations for Males and Females

<table>
<thead>
<tr>
<th>%Pre-test Conceptual Questions Total</th>
<th>Gender</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>44</td>
<td>9.4091</td>
<td>8.54351</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>58</td>
<td>12.8793</td>
<td>12.37864</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>%Pre-test Multiple-choice Questions Total</th>
<th>Gender</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>44</td>
<td>50.0000</td>
<td>21.88766</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>58</td>
<td>48.1034</td>
<td>21.06439</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>%Pre-test Total</th>
<th>Gender</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>44</td>
<td>19.8182</td>
<td>9.51687</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>58</td>
<td>21.9483</td>
<td>12.14593</td>
<td></td>
</tr>
</tbody>
</table>

A 2x3 analysis of covariance (ANCOVA) was conducted for the genetics unit to determine the effect of gender (male vs. female) and achievement levels (low, medium, and high) on post-test multiple-choice questions, post-test conceptual questions and post-test totals when controlling for unit 1 test scores. ANCOVA results (see table 10) indicated no significant main effects for multiple-choice questions (F (1,95) = .294, p = .589, partial \( \eta^2 = .003 \)), conceptual questions (F (1,95) = .270, p = .605, partial \( \eta^2 = .003 \)), or total test questions (F (1,95) = .403, p = .527, partial \( \eta^2 = .004 \)). Females outscored males in all three areas tested.
Table 10. Genetics Unit Post-Test Adjusted Means and Standard Error for Males and Females

<table>
<thead>
<tr>
<th></th>
<th>Gender</th>
<th>N</th>
<th>Adj. Mean</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>%Post-test Conceptual</td>
<td>Male</td>
<td>44</td>
<td>49.616</td>
<td>3.393</td>
</tr>
<tr>
<td>Questions Total</td>
<td>Female</td>
<td>58</td>
<td>51.921</td>
<td>2.862</td>
</tr>
<tr>
<td>%Post-test Multiple-choice Questions Total</td>
<td>Male</td>
<td>44</td>
<td>67.264</td>
<td>3.042</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>58</td>
<td>69.419</td>
<td>2.566</td>
</tr>
<tr>
<td>%Post-test Total</td>
<td>Male</td>
<td>44</td>
<td>54.151</td>
<td>2.839</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>58</td>
<td>56.509</td>
<td>2.395</td>
</tr>
</tbody>
</table>

Achievement Level

A one-way ANOVA was used to determine differences between achievement levels (low, medium, and high) for pre-test multiple choice questions, pre-test conceptual questions, and genetics pre-test total scores. One-way ANOVA results (see table 11) indicated no significant differences between groups (low, medium, and high) on multiple-choice questions \( F(2,99) = .474, p = .624 \), conceptual questions \( F(2,99) = .142, p = .868 \), or pre-test total \( F(2,99) = .256, p = .775 \). When looking at mean test scores, the medium achievement group scored higher than the other two on all three parts of the genetic pre-test.

Table 11. Genetics Unit Pre-Test Means and Standard Deviations for Achievement Level

<table>
<thead>
<tr>
<th></th>
<th>Achievement Level</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>%Pre-test Conceptual</td>
<td>Low</td>
<td>29</td>
<td>10.5862</td>
<td>9.18274</td>
</tr>
<tr>
<td>Questions Total</td>
<td>Medium</td>
<td>36</td>
<td>12.0556</td>
<td>11.34635</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>37</td>
<td>11.3514</td>
<td>12.10192</td>
</tr>
<tr>
<td>%Pre-test Multiple-Choice Questions Total</td>
<td>Low</td>
<td>29</td>
<td>50.0000</td>
<td>16.47509</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>36</td>
<td>50.8333</td>
<td>18.87932</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>37</td>
<td>46.2162</td>
<td>26.59901</td>
</tr>
<tr>
<td>%Pre-test Total</td>
<td>Low</td>
<td>29</td>
<td>20.6552</td>
<td>8.66963</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>36</td>
<td>22.0833</td>
<td>10.29390</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>37</td>
<td>20.2973</td>
<td>13.47810</td>
</tr>
</tbody>
</table>
ANCOVA results for achievement level (see table 12) indicated a significant main effect for multiple-choice questions ($F (2,95) = 3.530, p = .033, \text{partial } \eta^2 = .069$), but no significant main effects for conceptual questions ($F (2,95) = .653, p = .523, \text{partial } \eta^2 = .014$), or total test questions ($F (2,95) = 1.169, p = .315, \text{partial } \eta^2 = .024$). The low-achievement group outscored both the medium and high achievement groups on multiple-choice and total test scores. The low group also outscored the medium-achievement group on the conceptual questions total and was very close to the high group in that area.

Table 12. Genetic Unit Post-Test Adjusted Means and Standard Errors for Achievement Level

<table>
<thead>
<tr>
<th>Achievement Level</th>
<th>%Post-test Conceptual Questions Total</th>
<th>%Post-test Multiple-choice Questions Total</th>
<th>%Post-test Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>Adj. Mean</td>
<td>Std. Error</td>
</tr>
<tr>
<td>Low</td>
<td>29</td>
<td>52.458</td>
<td>4.350</td>
</tr>
<tr>
<td>Medium</td>
<td>36</td>
<td>47.284</td>
<td>3.675</td>
</tr>
<tr>
<td>High</td>
<td>37</td>
<td>52.563</td>
<td>3.653</td>
</tr>
</tbody>
</table>

**Improvement Scores**

A one-way ANOVA was used to measure improvement scores for the genetics unit between pre-test and post-test scores for both gender and achievement level. One-way ANOVA results (see table 13) indicated no significant differences existed between males and females on multiple-choice question improvement totals ($F (1,100) = 2.280, p = .134$), conceptual question improvement totals ($F (1,100) = .108, p = .743$) or total test
improvement scores (F (1,100) = .009, p = .925). It should be noted that in the second unit, males improved more than females on conceptual questions total scores. However, females improved more than males on both multiple-choice questions and total test scores.

Table 13. Genetics Unit Improvement Means and Standard Deviations for Males and Females

<table>
<thead>
<tr>
<th>Gender</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>44</td>
<td>.4613</td>
<td>.25606</td>
</tr>
<tr>
<td>Female</td>
<td>58</td>
<td>.4443</td>
<td>.26001</td>
</tr>
<tr>
<td>Male</td>
<td>44</td>
<td>.1228</td>
<td>.91149</td>
</tr>
<tr>
<td>Female</td>
<td>58</td>
<td>.3400</td>
<td>.53070</td>
</tr>
<tr>
<td>Male</td>
<td>44</td>
<td>.4378</td>
<td>.23285</td>
</tr>
<tr>
<td>Female</td>
<td>58</td>
<td>.4424</td>
<td>.24978</td>
</tr>
</tbody>
</table>

One-way ANOVA results (see table 14) indicated no significant differences between achievement levels (low, medium and high) on multiple-choice total improvement (F (2,99) = .646, p = .527), conceptual questions total improvement (F (2,99) = 2.520, p = .086), or total test improvement (F (2,99) = 2.514, p = .086). However, in all three areas tested, the low ability group improved more than the medium ability level group. On multiple-choice scores, the low achievement group even improved more than both the medium and high achievement groups.
Table 14. Genetics Unit Improvement Means and Standard Deviations for Achievement Level

<table>
<thead>
<tr>
<th>Improvement Scores</th>
<th>Achievement Level</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conceptual Questions Total</td>
<td>Low</td>
<td>29</td>
<td>.4242</td>
<td>.22307</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>36</td>
<td>.3983</td>
<td>.26102</td>
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<tr>
<td></td>
<td>High</td>
<td>37</td>
<td>.5250</td>
<td>.26764</td>
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<tr>
<td>Multiple-Choice Questions Total</td>
<td>Low</td>
<td>29</td>
<td>.3731</td>
<td>.54625</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>36</td>
<td>.2166</td>
<td>.69414</td>
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<tr>
<td></td>
<td>High</td>
<td>37</td>
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<td></td>
<td>Medium</td>
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<tr>
<td></td>
<td>High</td>
<td>37</td>
<td>.5041</td>
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</table>
CHAPTER 5. DISCUSSIONS, LIMITATIONS, AND IMPLICATIONS

This chapter will address the findings of the six research questions introduced at the beginning of the study. Each research question will be addressed individually while looking for patterns throughout the study. Limitations of the study will also be presented. The final portion of this chapter will present implications for other teachers or researchers interested in completing a similar study.

Discussion of Research Questions

The six research questions will be presented followed by discussion of results and what has been learned through completion of this study. Patterns in results between multiple-choice recall questions, conceptual higher order thinking questions, and total test results will be addressed throughout the discussion.

Cells Unit

*Question 1: Does student writing through using the SWH and restructured science activities lead to higher conceptual understanding of cells in one gender when compared to the other?*

At the beginning of the study, as reported in chapter 4, a statistical significance did exist between males and females on multiple-choice questions. It is important to note that multiple-choice questions are recall in nature while conceptual questions require higher-order thinking skills. In all three areas compared (multiple-choice totals, conceptual question totals, total test scores), males outscored females on the pre-test. After completing the unit on cells, the statistical significance between males and females on multiple-choice questions was eliminated. However, males still scored higher on the multiple-choice questions than females. By the end of one unit using the SWH, females outscored males on conceptual questions and total test scores.
Question 2: Does student writing through using the SWH and restructured science activities lead to higher conceptual understanding of cells in one achievement group over another?

At the beginning of the study, a statistical significance did exist between low, medium, and high achievement students on both multiple-choice question totals and total test scores. In all three areas compared, the low achievement group had the lowest mean while the high achievement group had the highest mean. After the unit on cells was complete, the statistical significance between achievement groups on multiple-choice and total test scores was eliminated. At the end of one unit using the SWH, the low achievement group outperformed the medium achievement group in all three areas tested.

Question 3: Does student improvement at the end of the cells unit differ by gender or achievement level?

Student improvement at the end of the cells unit was measured by gender and achievement level. No statistical differences existed between males and females in multiple-choice questions, conceptual questions, or total test improvement scores. Females did improve slightly more than males on both conceptual question totals and total test scores while males improved more than females on multiple-choice recall questions.

When comparing achievement level improvement scores, significant differences occurred in both conceptual question totals and total test improvement scores. No significant differences existed on multiple-choice improvement scores. In all three areas tested, the low achievement group improved more than the medium achievement group. The high achievement group improved the most in all three areas.
Genetics Unit

Question 4: Does student writing through using the SWH and restructured science activities lead to higher conceptual understanding of genetics in one gender when compared to the other?

At the beginning of the unit on genetics, as reported in chapter 4, no statistical significance existed between males and females on the three areas tested. These results remained consistent with results from the cell’s post test. Female students continued to score higher on both conceptual questions and the total test while male students continued to score higher on the multiple-choice recall questions. At the completion of the unit on genetics, results remained consistent with no statistical significance between males and females on all three areas measured. One item of interest was that females now outscored males on all three areas measured: multiple-choice recall questions, conceptual higher-order thinking questions and total test scores.

Question 5: Does student writing through using the SWH and restructured science activities lead to higher conceptual understanding of genetics in one achievement group over another?

No statistical significance existed between low, medium and high achievement groups at the beginning of the unit covering genetics. One interesting finding was that prior to the unit on genetics, the medium achievement students outscored both low and high achievement groups in all three areas tested. This was a change from the end of the cell’s unit when the low achievement students outscored the medium achievement students. Once the unit on genetics was complete, a statistical significance did exist on recall multiple-choice questions between low, medium and high achievement groups. No statistical significance existed on conceptual questions or total test scores. When comparing test means, the low
achievement group outperformed the medium group again in all three areas and even outperformed the high achievement group on both conceptual question totals and total test scores.

Question 6: Does student improvement at the end of the genetics unit differ by gender or achievement level?

Student improvement at the end of the genetics unit was measured by both gender and achievement level. No statistical significance existed between males and females at the end of the unit on genetics in all three areas measured. Females showed a greater improvement score for multiple-choice recall questions while males showed a greater improvement in conceptual higher-order thinking questions. Mean improvement scores for the total test were very close together.

Significant differences did not exist when comparing improvement scores for low, medium, and high achievement groups after the genetics unit. The significant differences that did exist in achievement level for the cell's unit have been eliminated. Once again, the low achievement group improved more than the medium achievement group in all three areas and even improved more than the high achievement group on multiple-choice recall questions.

Summary

In summary, a few major points emerge from this study. Statistically significant results existed between males and females in multiple-choice recall questions at the beginning of the study with males significantly outperforming females. By the end of the first unit, this statistical significance had been eliminated and this remained consistent throughout the second unit. Statistically significant results also existed between achievement levels at the beginning of the study in both multiple-choice recall questions and total test scores. By the
end of the first unit the significance between groups had been eliminated and this remained
the case until the end of the second unit when the significance reappeared in the multiple-
choice recall questions. After further investigation, the initial significance between groups
was due to the interaction between the low and high achievement groups with the high group
outperforming the low group. At the end of the second unit, this trend was reversed with the
significance due to the interaction between the low and medium achievement groups and the
low and high achievement groups with the low group outperforming both the medium and
high achievement groups on multiple-choice recall questions.

While not statistically significant, some trends were noted by the researcher between
males and females and the three achievement levels. At the beginning of the cell's unit,
males outscored females in all three areas tested. However, after the first unit using the SWH,
females outperformed the males on conceptual questions and total test scores and continued
to do so through the second unit on genetics. By the end of the genetics unit, females were
even outscoring males in the third area tested, multiple-choice recall questions. At the
beginning of the study, the low achievement students had the lowest means in all three areas
tested. By the end of the first unit using the SWH, the low achievement students
outperformed the medium achievement students and continued to do so through the unit on
genetics with one exception, the genetics pre-test scores. By the end of the second unit on
genetics, the low achievement students were even outperforming the high achievement
students on higher-order conceptual questions and total test scores.

Limitations of the Study

Five main limitations of the study were noted by the researcher: attendance, student
apathy, the researcher, adjustment time and the pre/post tests.
Attendance

One area of concern throughout the study was the attendance of the participants during the activities using the science writing heuristic. Eight total activities were used during the study using the science writing heuristic. Each activity spanned two or more days of brainstorming ideas, designing and completing the experiments, and presentation of claims and evidence classmates. Students who were absent during these critical portions of the discussion and experiments were required to make them up with the researcher before or after school time. However, the exact environment created during actual class time is impossible to reproduce during a make up session. It must also be noted that a few students may have chosen not to make up an entire SWH activity.

Student Apathy

While each student was provided the same environment and opportunities to complete the writing heuristic activities, not all students took advantage of this in the classroom. The researcher found that some students did not fully engage in the experiments, discussions, and writing activities during the two units of study. Students were encouraged by the researcher to become more actively involved, but as mentioned earlier in chapter 2, students ultimately have control over their learning. The researcher noted that those students who did not actively complete the writing activities were less likely to put forth a great deal of effort on the writing portion of the post-test questions.

Researcher Experience

Implementing the science writing heuristic into the classroom is challenging and requires a great deal of patience, perseverance, and flexibility. While the researcher has had almost three years of experience using the SWH, she is certainly not an expert. Careful
questioning and constant interaction with the students in the classroom is essential to the success of the writing heuristic. Providing feedback on writing assignments for approximately 115 students is also a challenge. The researcher struggled with those students who continue to have misconceptions at the end of the SWH activities. Careful attention to teacher behaviors mentioned in the literature review and fine tuning of SWH activities will be important for future effectiveness of the SWH.

Adjustment Time

Traditionally in science, students have been very comfortable with teacher direction and a standard lab format (i.e. purpose, procedure, data, etc.) during experiment. The introduction of the SWH asks students to change the type of writing they are used to in science. The constructivist approach to learning asks the students to take much more responsibility for their learning and the interactions in the classroom. Students are taken out of the role of following a cookbook recipe and put into the role of constructing the recipe themselves. This makes many students very uncomfortable and often times frustrated with the activities. The students that were found to be the most frustrated were the high achievement students who were used to one way of doing science activities and working toward one correct answer.

Pre/Post Tests

The final limitations of the study were the pre/post tests for each unit. The tests were designed by the researcher using two sources: an exam generator and the AP biology test. Multiple-choice recall questions were taken from the exam generator while the essay questions were designed using the AP biology test. While the researcher used these tools to
assist in writing a test to carefully measure all three big ideas for each unit, the tests may have not have equally assessed all three ideas.

**Implications**

There are four implications arising from this study.

The largest area of concern resulting from this study were the medium achievement level students. They seemed to be falling through the cracks and had the smallest impact, if any, from using the SWH. More research needs to be done to determine why the SWH seems to have an impact on both low and high achievement level students, but not medium achievement level students.

More research also needs to be done regarding the low achievement level students. Traditionally, these students have done poorly in science classes, however, they seemed to have the largest impact from using the SWH. It may be beneficial to conduct further studies to determine what particular portion of using the SWH causes these students to perform so well. Further studies may focus on the discussion and class negotiations between these students, different types of writing done by the students, or their overall learning styles.

This study was performed in one biology classroom involving approximately 115 students and one teacher. A larger scale study needs to be performed involving more biology classes and more teachers to support claims involving the SWH on a wide-scale basis. Different subjects in science may also be examined, chemistry, physics, or earth science, which may also involve different grade levels and ages of students.

Finally, a more in depth study could be conducted comparing low achievement level males and females, medium achievement level males and females and high achievement level males and females. Gender and ability level could be broken down and studied to determine
which students, males or females, have the greater impact from using the SWH in each achievement level.
APPENDIX A. MURDER MYSTERY ACTIVITY

Day 1

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 Mr. Xavier was found dead in his home early this morning by the servants. 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 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.

Based on these preliminary observations, please work with your partner to draw initial conclusions about what happened. Please provide as much evidence as you can to support each conclusion you make.
New Information! Detectives investigating the death of Mr. Xavier have found some additional information. Due to his paranoid nature, Mr. Xavier always had Kurt Wagner, the butler, lock all doors to the mansion at night. However, detectives found that the back door had in fact been left open. Detectives found that the chef, Robert Drake, had been the last employee to leave that night. When questioned, Mr. Drake stated that the doors are supposed to lock behind him when he leaves. In addition, a bottle of medication for high cholesterol was discovered in the medicine cabinet. Also, the carpet in the dining room was wet.

With all this information, come up with a single claim and supporting evidence that explains how Mr. Xavier died.
APPENDIX B. CELL PRE AND POST TEST

Cells Test

Name: 

1) According to the cell theory, which statement is correct?
   A) Viruses are true cells.
   B) Mitochondria are found only in plant cells.
   C) Cells come from preexisting cells.
   D) Cells are basically unlike in structure.

2) Microscopic examination of an animal cell reveals the presence of a plasma membrane but no cell wall. Which additional structures would normally be present within this cell?
   A) centrioles
   B) chloroplasts
   C) large vacuoles
   D) starch grains

3) Which cell organelles are the sites of aerobic cellular respiration in both plant and animal cells?
   A) chloroplasts
   B) centrosomes
   C) nuclei
   D) mitochondria

4) Which cellular organelle is represented by the diagram below?

   protein molecules
   lipid molecules

   A) centriole
   B) plasma membrane
   C) ribosome
   D) cell wall

5) Which statement best describes the plasma membrane of a living plant cell?
   A) It has the same permeability to all substances found inside or outside the cell.
   B) It is composed of proteins and carbohydrates only.
   C) It selectively regulates the passage of substances into and out of the cell.
   D) It is a double protein layer with floating lipid molecules.

6) Which process requires the expenditure of cellular energy?
   A) osmosis
   B) active transport
   C) diffusion
   D) passive transport

7) Human red blood cells placed in a 2% salt solution appear to shrink, but those placed in a 0.4% salt solution burst. Which statement best supports these observations?
   A) The nucleus does not regulate water balance in a cell.
   B) Salt is actively transported across cell membranes.
   C) Salt causes cell walls to swell.
   D) Osmosis may occur in either direction across the cell membrane.

8) In the diagram of a cell below, the structure labeled X enables the cell to

   A) release energy
   B) store waste products
   C) manufacture proteins
   D) control nuclear division
9) A student was given a beaker containing distilled water and a separate smaller beaker containing a solution of methylene blue. The student was directed to carefully lower the smaller beaker into the larger beaker. He observed that the methylene blue began to disperse into the distilled water, as shown in the diagram below.

Which process was most likely responsible for the observed changes?

A) pinocytosis  B) osmosis  C) diffusion  D) active transport

10) Molecules that are too large to pass through the pores of a cell membrane may enter the cell by a process known as

A) synthesis  B) pinocytosis  C) cyclosis  D) hydrolysis

Essay Questions - B

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

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

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

4. Compare and contrast the cells of spinach (plant cells) and the cells of dogs (animal cells). Include at least 3 comparisons in your answer.
APPENDIX C. GENETICS PRE AND POST TEST

Genetics Test

Multiple Choice:
01. Different forms of a gene are called
a. hybrids.  
b. dominant factors.  
c. alleles.  
d. recessive factors.

02. If a homozygous tall pea plant and a homozygous short pea plant are crossed,
a. the recessive trait disappears.  
b. the offspring are of medium height.  
c. no hybrids are produced.  
d. all the offspring are short.

03. Organisms that have two identical alleles for a particular trait are said to be
a. hybrid.  
b. heterozygous.  
c. homozygous.  
d. dominant.

04. Unlike mitosis, meiosis results in the formation of
a. two haploid cells.  
b. three diploid polar bodies.  
c. four diploid gamete cells.  
d. four haploid gamete cells.

05. A scientist analyzed several DNA samples to determine the relative proportions of purine and pyrimidine bases. Her data is summarized in the table below.

<table>
<thead>
<tr>
<th>Sample</th>
<th>G</th>
<th>C</th>
<th>A</th>
<th>T</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>35</td>
<td>35</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>B</td>
<td>40</td>
<td>10</td>
<td>40</td>
<td>10</td>
</tr>
<tr>
<td>C</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
</tr>
</tbody>
</table>

Which sample(s) support the base-pairing rule?
a. Sample A only.  
b. Sample B only.  
c. Samples A and C.  
d. Samples A, B, and C.

06. A nucleotide does NOT contain
a. a 5-carbon sugar.  
b. polymerase.  
c. a nitrogen base.  
d. a phosphate group.

07. The process by which the genetic code of DNA is copied into a strand of RNA is called
a. translation.  
b. transcription.  
c. transformation.  
d. replication.

08. Varieties of purebred dogs are maintained by
a. selective breeding.  
b. hybridization.  
c. inbreeding.  
d. genetic engineering.
09. A child is colorblind. Which genotype-phenotype combination is NOT possible in the child's parents?
   a. The father does not carry the allele and is not colorblind.
   b. The mother carries one allele but is not colorblind.
   c. The father carries one allele but is not colorblind.
   d. The father carries one allele and is colorblind.

10. Most sex-linked genes are found on the
   a. Y chromosome.
   b. O chromosome.
   c. YY chromosome
   d. X chromosome.

Conceptual Questions:
11. In sheep, the allele for white wool (A) is dominant over the allele for black wool (a). Explain in writing how you would determine the genotype of a white ram, or male sheep.

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

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

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


Blosser, P. E. (1990). How to ask the right questions. NSTA.


