ABSTRACT

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The use of drawing in the classroom has a contentious history in the U.S. education system. While most instructors and students agree that the activity helps students focus and observe more details, there is a lack of empirical data to support these positions. This study examines the use of three treatments (writing a description, drawing a perceptual image, or drawing a perceptual image after participating in a short instructional lesson on perceptual drawing) each week over the course of a semester. The students in the “Drawing with Instruction” group exhibit a small but significantly higher level of content knowledge by the end of the semester. When comparing Attitude Toward Biology and Observational Skills among the three groups, inconclusive results restrict making any conclusions. Student perceptions of the task are positive, although not as strong as indicated by other studies.

A student behavior observed during the first study led to another question regarding student cognitive processes, and demonstrated cognitive change in student-rendered drawings. The data from the second study indicate that hemispheric dominance or visual/verbal learning do not impact learning from perceptual drawing activities. However, conservatism and need for closure are inversely proportional to the change seen in student drawings over the course of a lesson. Further research is needed to verify these conclusions, as the second study has a small number of participants.
Perceptual Drawing as a Learning Tool in a College Biology Laboratory

by
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BIOGRAPHY

Jennifer Landin grew up in Michigan, where she and her friend Alana spent time practicing musical instruments and dressing up as McDonald’s meals for Halloween. At a young age, Aunt Bonnie taught Jennifer how to make peanut butter and jelly sandwiches that won’t get soggy, a skill used frequently throughout her graduate career.

Jennifer attended the University of Georgia and University of Montana for her undergraduate degree in Forestry and Wildlife Management. During this time, she trapped bobcats and alligators, began a morbid fascination with bones and skulls, and spent summers feeding rats and inoculating corn with fungus.

Jennifer earned a Master’s degree in Biology from Marshall University, where she learned that it is much easier to trap newts than bobcats or alligators. She also spent many hours at the Calamity Café preparing for herpetology class with her lab-mates Alison, Sandy, Bart, and Brock.

After a few years out in the real-world, Jennifer realized that it wasn’t living up to the hype. She rejoined Academia and hopes to stay there. She began a career in teaching at the NC State Department of Biology in 2009. Her hobbies include illustration and watercolor, admiring Darwin, and scrunchie-theft.
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TABLE OF CONTENTS

LIST OF TABLES.......................................................................................................................... viii

LIST OF FIGURES ....................................................................................................................... ix

CHAPTER 1: INTRODUCTION........................................................................................................ 1
  Importance of Observation and Drawing ............................................................................... 1
  Levels of Observational Skills............................................................................................... 2
  History of Higher Education and Advanced Observational Skills ....................................... 3
  Significance of Study ............................................................................................................. 5
  Purpose of Study ................................................................................................................... 6
  Research Questions ............................................................................................................... 6
  Assumptions .......................................................................................................................... 7
  Definitions of Terms ............................................................................................................. 8

CHAPTER 2: LITERATURE REVIEW .......................................................................................... 11
  Theoretical Framework for Study ....................................................................................... 12
  Application of Conceptual Change Theory to Drawing ..................................................... 14
  Conceptual Change Theory and Visual Perception ........................................................... 18
  Conceptual Change Theory and Neurological Variation .................................................... 20
  Drawing and Biology Content Knowledge (RQ1) .............................................................. 22
    Difficulties with Studying Drawing as a Learning Tool ....................................................... 27
  Drawing and Attitude Toward Biology (RQ2) ....................................................................... 29
  Drawing and Observational Skills (RQ3) ............................................................................. 31
  Student Perceptions of Drawing Activities (RQ4) ............................................................... 34
  Conceptual Change and Individual Cognitive Processes (RQ5) .......................................... 36
  Summary ............................................................................................................................... 38

CHAPTER 3: METHODS ............................................................................................................ 39
  Pilot Study .............................................................................................................................. 39
    Pilot Study - Research Design and Methods ................................................................. 40
    Pilot Study – Testing and Activity Analysis ...................................................................... 40
    Pilot Study – Results and Conclusions .......................................................................... 42
  Study One ............................................................................................................................. 45
    Study One – Research Design ......................................................................................... 46
    Study One – Study Participants ....................................................................................... 48
    Study One – Materials ....................................................................................................... 49
    Study One – Instrumentation and Scoring ....................................................................... 49
    Study One – Statistical Analysis ..................................................................................... 52
  Study Two ............................................................................................................................ 52
LIST OF TABLES

Table 1. Results from Pilot Study Pre-/Post-tests (Knowledge, Attitude, and Observational Skills) ................................................................. 43

Table 2. Average Responses of the Three Treatment Group to Question about Observation of Details .......................................................................................................................... 76

Table 3. Percent of Student Preference for Type of Assignment (by Treatment Group) ...... 81

Table 4. Student Perceptions of Enjoyment of Class if Presented with Different Assignments (by Treatment Group) ......................................................... 82
LIST OF FIGURES

Figure 1. Visual Representation of Posner’s Theory of Conceptual Change ......................... 15
Figure 2. Visual Representation of Modified Theory of Conceptual Change ........................ 17
Figure 3. Examples of Gestalt visual processing (from Smith, 1988)................................. 32
Figure 4. Visual representation of Experimental Design for Study One. ............................... 48
Figure 5. Object of Observational Skills Assessment with two samples of different skill levels (scores of 29/31 [middle sample] and 11/31 [sample on right]) ........................................ 51
Figure 6. Pre-/Post-Test Results from Treatment Groups (Content Knowledge) * denotes statistical difference between treatment groups ................................................................. 58
Figure 7. Improvement in Content Knowledge between the Three Treatment Groups ........ 59
Figure 8. Examples of detailed visual descriptions (top row) and imprecise visual descriptions (bottom row). ................................................................. 61
Figure 9. Results of Pre-/Post-Tests of Attitude between the Three Treatment Groups ...... 66
Figure 10. Increase in Attitude Scores Among the Three Treatment Groups .................... 66
Figure 11. Student Opinions of Pride in Assignments (by Treatment Group) .................... 68
Figure 12. Pre-/Post-Test Results of the Observational Skills Assessment (OSA) for all Three Treatment Groups ................................................................. 69
Figure 13. Average OSA Scores for Science majors and Non-science majors .................... 70
Figure 14. Average OSA Scores for A-, B-, and C-students ............................................. 72
Figure 15. Scores of Weekly Assignments over Time (Drawing and Drawing with Instruction groups) ........................................................................ 73
Figure 16. Examples of Scoring of Student Lab Drawings ............................................. 74
Figure 17. Student Perceptions of Increase in Knowledge between Treatment Groups ...... 81
Figure 18. Examples of Drawings Produced by Students Exhibiting Looking and Non-Looking Behaviors

Figure 19. Examples of Different Levels of Cognitive Change between pre-lab conceptual drawings and during-lab perceptual drawings (Category 1 and Category 5)

Figure 20. Average Scores on the Conservative Issues Scale among Different Levels of Cognitive Change (by Conceptual or Perceptual Level of Observational Drawings)

Figure 21. Average Scores on the Need for Closure Scale among Different Levels of Cognitive Change (by Conceptual or Perceptual Level of Observational Drawings)

Figure 22. Visual Representation of Theoretical Framework, Incorporating Data Collected from this Study
In the current educational system, art and science classes are seen as two exclusive subjects. However, drawing as a learning tool in biology has a long history in the United States educational system. Massachusetts passed the country’s first “Drawing Act” in 1870, which required that drawing be included as one of nine essential subjects taught in all state public schools. By 1898, newly-hired teachers in New York were expected to pass a proficiency exam in drawing skills (Times, 1898). These drawing skills were described as “industrial” rather than “ornamental”; they were included with geography, math and science skills, rather than with English, history and civics.

Many college instructors perceive drawing as a mechanism to force students to focus on specimens and pay close attention to detail (Alkaslassy & O'Day, 2002; Bland, 2004; Matern & Feliciano, 2000). While many instructors hold beliefs that these positive outcomes develop from drawing, empirical evidence of these conclusions is incomplete, conflicting or inconclusive. This study explores the discrepancy between perceptions about drawing and the empirical evidence regarding the use of drawing as an educational tool.

Importance of Observation and Drawing

Observation is acknowledged as an important science process skill. The scientific method contains two steps that involve observational skills: recognition of an anomalous event and data collection (Campbell & Reece, 2005). In biology, observation is used to compare and contrast, notice unusual attributes or patterns of specimens, identify organisms,
examine motion and behavior, and relate form to function. Examples of important observations in biology include discoveries of microscopic organisms by von Leeuwenhoek, jumping genes by McClintock, and natural selection by Darwin and Wallace.

Drawings can serve as a record of these observations and as a visual form of communication. Throughout the history of biology, drawings held a prominent place as they were expertly utilized by famous anatomists, explorers, microbiologists and taxonomists. In education, line drawings have been used in textbooks to communicate concepts and structures. Historically, illustrations were limited in number, easy to comprehend, and simple enough for students to recreate in their notebooks. Since the 1970s, advances in graphics and the printing process allowed textbook figures to be more colorful, computerized and analytical. This shift has raised questions about the effectiveness of these figures in comparison to simpler, black-and-white line drawings (Ametller & Pinto, 2002; Cook, 2008; 2002; Van Meter, 2010).

Levels of Observational Skills

Observation is a recognized process skill for primary school students. However, these observational skills are basic. They include tasks such as describing general color or texture, or taking simple measurements. As education progresses, student skills and knowledge increases. In the case of observational skills, more mature students ought to be able to differentiate visual cues on a finer scale. However, instruction in more advanced observational skills is lacking in secondary and post-secondary education (Alkaslassy & O'Day, 2002).
Instruction in these advanced observational skills is often a focus of professional training for employees working in diverse fields. The medical community is acutely aware of a correlation between observational and diagnostic skills (Bardes, Gillers, & Herman, 2001; Dolev, Friedlaender, & Braverman, 2001; Kirklin, Duncan, McBride, Hunt, & Griffin, 2007; Rodenhauser, Stricland, & Gambala, 2004). Social workers and psychologists also need strong observational skills for interpreting visual behavioral cues of their clients (fOCUS, 2009; Sheridan, 2008). Law-enforcement recruits are given observational skills tests as part of their application materials prior to hiring, since a keen ability to notice and remember detail is important for recollection of a crime scene or suspect, as well as for securing evidence (Dahl, 1952; Lindquist, 2008). Daniel Pink, contributing editor to WIRED magazine (a periodical for web developers and technology enthusiasts), writes of the importance of discriminating observation for business and IT professionals. He promotes the ability to distinguish detail and observe design as a route to improve and increase creativity (Pink, 2006).

History of Higher Education and Advanced Observational Skills

Historically, advanced observational skills were taught to older students (Efland, 1990). For example, students studying the natural sciences at North Carolina State University (then, the North Carolina College of Agriculture and Mechanic Arts) at the turn of the 20th century were required to take drawing classes for one hour daily – five credit hours per semester. The purpose of this drawing course was to “learn to observe and become familiar with the little details incident to agricultural pursuits” (Catalogue of the NC College of Agriculture and
Mechanic Arts, 1890). This requirement was not unusual at the time. From a personal example, I recently found a trade school notebook belonging to my grandfather (circa 1929) listing his course schedule as 3 hours of electricity, 1 hour of geometry, 1 hour of commercial art, 2 hours of mechanical drawing and 1 hour of English (Piascik, 1929). Until the 1930s, drawing was a common skill and educational approach used in the American school system.

Changes to education around the 1930s reduced or eliminated drawing from upper-level science curricula in the United States. These changes included sharp increases in the student population due to immigration, urbanization and child labor laws, new technologies like the camera and mimeograph, and the national efficiency movement. Reasons cited by educators for the removal of drawing from science classes were based on social climate and a desire to utilize the newest time-saving technology. While many experiments were conducted into the effectiveness of drawing as a learning tool, little data were collected to examine both benefits and disadvantages of drawing in education. Such studies would have allowed educators to make a more informed decision about the inclusion of drawing in the science classroom.

In the current educational climate, there are no requirements for developing advanced observational skills. Only basic observational skills are recognized as an important objective for elementary-level students. Similarly, drawing is commonly viewed as a child’s activity. Elementary school teachers keep their classrooms stocked with crayons, markers, and pens to allow children to express themselves creatively. By middle school, art supplies are limited to specific art classes and many high schools have dissolved their art courses entirely. This loss of advanced drawing curricula can directly affect advanced observational skills. It is
important to acknowledge that the ability to observe closely is a skill that must be taught and learned. It is NOT, as so many are inclined to believe, a ‘gift’ or ‘talent’ bestowed at birth.

Significance of Study

This study addressed two factors: drawing to improve observational skills (as a tool for learning); and drawing to increase understanding or conceptual change (as a means to learning). For improving observational skills, drawing requires careful attention be paid to an object. This attention allows students time to notice smaller details and remember those details more clearly than if they’d just glanced at the object or listened to an instructor describe the object. Drawing also encourages a creative, multidisciplinary approach to learning science. This approach may promote interest, creativity and curiosity, which can improve focus in observation and attentiveness for learning.

Since drawing forces students to slow down and pay careful attention to details in objects, these observations may allow a student to notice details that conflict with their pre-conceived notions. The conflict can impact cognitive processes as the student tries to reconcile their understanding with their observations. Because drawings are based on direct observation, they follow a scientific process of collecting data and then interpreting a conclusion, rather than maintaining a current belief.

However, there are differences in individual cognitive processes. A single approach to learning may have different levels of effectiveness in different students. In this study, cognitive differences were examined for any correlation with the effectiveness of drawing tasks and observational skills. These cognitive differences include conservatism and need for
closure, brain hemispheric dominance, spatial abilities, and learning style (verbal/visual or sequential/global). There are controversies associated with cognitive measures; these concerns are addressed further in subsequent chapters.

Purpose of Study

The two purposes of this study were to examine drawing as a learning tool through observational skills and as a means to learning through conceptual change. To test the first purpose, drawing was compared to writing in terms of overall performance in class, student attitudes, and student perceptions of the learning-based assignment. Students were pre- and post-tested to determine whether the drawing activities actually increased observational skills. The second purpose of this study was to investigate differences in cognitive processes. Such differences may address the discrepancy between empirical studies and the perceived benefits of conceptual change by using drawing as a learning tool. Conclusions from this research may be used to increase the effectiveness in use of drawing as a teaching tool.

Research Questions

1. Do students who participate in weekly drawing activities demonstrate a higher level of biology content knowledge when compared to students who participate in weekly writing activities?

2. Do students who participate in weekly drawing activities show a more positive attitude toward biology when compared to students who participate in weekly writing activities?
3. Do students who participate in weekly drawing activities display improved observational skills when compared to students who participate in weekly writing activities?

4. What are student perceptions of drawing activities in relation to biological understanding?

5. Are there correlations between the gains in content knowledge related to drawing activities and student cognitive processes? (Cognitive processes include conservatism, need for closure, spatial ability, learning style [visual/verbal or sequential/global], and brain hemispheric dominance.)

Assumptions

Hypotheses for this study were that students who participated in weekly drawing activities would demonstrate a 1) slightly higher level of biology content knowledge; 2) more positive attitude toward biology; and 3) higher level of observational skills when compared to students who participated in weekly writing activities only. Also, if all students are assigned drawing activities, some students would demonstrate greater improvement in knowledge, attitude or observational skills than others. Those students may cognitively process information in a more visually-based way, or demonstrate a lower need for closure or level of conservatism.

 Limitations on this study include methodological and theoretical assumptions, as well as personal biases. The methodological assumptions are that the populations of students
involved in this study were representative, and that the students were accurately reporting information requested.

In the first study, students were randomly assigned to treatment groups, but these students may not have been representative of college students as a whole since they were all biology majors. The treatment was a part of the students’ laboratory grade, so all students completed treatment assignments. There was no control group. In the second study, all students received the same treatment, but their cognitive group remained unknown to the investigator until the completion of the semester. However, since the investigator was the instructor of the course, the students’ conservatism or learning styles may have become apparent as the semester progressed. Finally, the first and second studies had no replications.

My personal biases included expectations that drawing does improve observation of details. As an artist, art teacher and biologist, my personal experiences include many instances when I’ve drawn an object and noticed a structure that I had surprisingly overlooked while previously viewing it. While this bias is detrimental to the validity of the work, it is also the reason behind the research. I have tried to design the research as empirically as possible to reduce my biases in the results.

Definitions of Terms

- Observation – receiving of external data through the senses; throughout this study, observation refers to receiving visual external data through the eyes.
- Observational skill – the level of ability to perceive visual data;
o basic observational skills refer to general measurements, basic shapes, colors and textures;

o advanced observational skills, or perceptual skills, refer to visual perception of fine details of an object (e.g. small structures, gradations, differences in fine textures, etc.).

- Drawing – representation of an object by means of lines and shading, a sketch:
  
o Observational drawings or perceptual drawings (a.k.a. description depiction) are made with the purpose of creating a life-like representation of the object. The illustrator must be directly observing the object while drawing.
  
o Conceptual drawings (a.k.a. memory drawing, intrinsic depiction) are those which the drawer has no sensory access to the object being drawn.
  
o A representative drawing “reproduces as accurately as possible the exact appearance of an object” (Ayer, 1916) and is the desired outcome of an observational drawing. This term refers to an end product, whereas "observational drawing" or "perceptual drawing" is a mode of creating the product.
  
o Analytical drawings are graphical representations of concepts (e.g. a stick figure or heart icon) and are greatly simplified versions of representative drawings. These drawings are often, though not always, the result of conceptual drawings.
  
o Industrial drawings are made for the purpose of communication, documentation or education. They often rely on accurate measurements and proportion. They may be either perceptual or conceptual.
  
o Ornamental drawings are made for the purpose of aesthetics only.
• Perception – the process of receiving and being aware of visual information. Perceptions resulting from direct observation may be correct or incorrect (misperceptions). Misperceptions are most often the result of pre-conceptual assumptions and inattention, or misinterpretations of the visual data.

NOTE: Visual perception will be addressed as visual or sensory perception. Perceptions of an activity will be referred to as student perceptions, or opinion.

• Conception – the process of creating or understanding mental concepts. Conceptions may be accurately concluded from the correct perceptual information, or inaccurately concluded (misconception). Misconceptions may result from misperceptions, perception of inaccurate material, or from inattention.

• Conservatism – self-described political affiliation or opinions toward social issues.
CHAPTER 2: LITERATURE REVIEW

The educational attitudes toward drawing in science classes have been examined since the early 20th century. Despite this long history of interest in drawing, no consensus has yet been reached on the significance of drawing in relation to student content knowledge, attitude toward biology, or observational skills.

The effectiveness of drawing as a learning tool seems tied to investigator perceptions rather than data. These opinions have changed depending on social and educational climate. In general, positive perceptions revolve around drawing as a tool to focus attention and closely observe details. The negative position centers on the lack of student drawing skills and an excessive amount of time spent on the activity. Both stances refer to student enjoyment of drawing; the pro-drawing group cites student satisfaction in the activity and the anti-drawing group cites student frustration.

It is important to acknowledge that student focus, attention, and drawing ability or enjoyment are difficult subjects to research. While a student’s opinion of his/her focus, attention, abilities and enjoyment can be measured, objective measures of focus and attention are more complex and challenging to administer. Drawing abilities and enjoyment are difficult to define and quantify. Therefore, much of the data collected in this field of research is interpreted, and may be more prone to the bias of the researcher or social climate.
Theoretical Framework for Study

In this study, the educational theory of conceptual change is the foundation through which data will be interpreted. This framework will be investigated in two stages: 1) observational skills leading to visual perception of object; and 2) visual perception leading to conceptual change.

The theoretical framework of this research is based on Posner’s Theory of Conceptual Change (Posner, Strike, Hewson, & Gertzog, 1982). In general, Posner’s theory states that if plausible new evidence contradicts unstable preconceived notions, conceptual change will occur. Posner based his theory on the educational research of Jean Piaget, Gestalt theorists’ descriptions of cognitive influences on visual perception, and Thomas Kuhn’s writing on scientific paradigm shifts. Conceptual change combines these three fields by describing how preconceptions influence the intake of new information. If the new information cannot be incorporated into the current mental schema, then radical shifts in conception will occur. Posner considers that conceptual change usually does not occur in one linear progression, but occurs gradually and erratically.

There are two major assumptions of Posner’s theory: 1) that the student will correctly observe new evidence, and 2) that the students’ minds are capable of conceptual change. The research conducted in this study addresses these two assumptions.

The first assumption involves observation and perception. The more carefully and attentively observations are made, the more likely those observations will be visually perceived correctly. Cognitive research has shown how visual signals may be ignored in a condition called Inattention Blindness, or misinterpreted according to Gestalt Theory (Cohen
& Bennett, 1997; Mack & Rock, 1999; Simons & Chabris, 1999; Smith, 1988). Drawing an object forces attention on the specimen and requires the illustrator to isolate small sections of the object. Thus, observations will more likely be processed correctly.

The second assumption of conceptual change involves perception and cognition. Posner’s theory of conceptual change states that if the sensory perception matches the preconceived notion, no cognitive change will occur. If the perception differs from the preconception, that conflict will result in cognitive change. This presupposes that all students’ minds will function the same way when faced with cognitive conflict. While Posner did address the circuitousness of the process by stating that the change is gradual, he did not address that for some students conceptual change may be achieved more slowly, or not at all, when compared to other students. Some students, when faced with cognitive conflict, may disregard the new information rather than change their preconceptions.

Neurological data have indicated that different activity levels in brain structures may result in differences in acceptance of new information. One example of such a brain structure, the anterior cingulate cortex (ACC), is involved in learning by detecting errors and preventing future errors (Braver, Barch, Gray, Molfese, & Snyder, 2001; Carter et al., 1998; Yeung, Botvinick, & Cohen, 2004). As a result of differences in the developmental formation of the ACC, some people will slow down and focus more closely to prevent future errors, while others will keep a faster pace and accept the errors. When making drawings of specimens, students of all skill levels make perceptual mistakes. These students must first recognize the errors and then decide to correct them or accept them. In other words, if the student disregards new information, they can remain satisfied with their existing conception.
This aspect of perceptual drawing incorporates attention and error detection in student
drawing assignments.

Thus, the educational theory of conceptual change is the framework for this study and
the research questions address the two steps in that process. Drawing as a learning tool is
examined for its effect on the students' intake of new information and the students' ability to
accept that data, allowing conceptual change to occur.

Application of Conceptual Change Theory to Drawing

Educational research on drawing as a learning tool in the science classroom is lacking a
dominant theoretical framework. Brooks (2009) addresses this concern and suggests that two
frameworks, one based on Piaget’s cognitive development and another based on aesthetics
(or an art-based framework), are most common. She proposes the use of a Vygotskian
framework because the drawing in her research is used for a communicative purpose.

Because this study addresses the cognitive functions associated with drawing as a
learning tool, I've chosen a theoretical framework based on Piaget's research in cognition.
The theory of conceptual change describes two ways of sorting new data or experiences
cognitively: 1) assimilation, when the new information matches with previous concepts; and
2) accommodation, when new information causes the learner to replace or reorganize
previous concepts.

Posner et al. (1982) questioned “when will individuals find it reasonable to undertake a
major reorganization of their current concepts or to replace one set of central concepts with
another?” (p.213). He answered this question with a set of four requirements for new
information to replace the current knowledge: 1) dissatisfaction with existing conception; 2) new conception is intelligible; 3) new conception is plausible; 4) new conception opens new inquiries (Figure 1).

![Diagram of Posner's Theory of Conceptual Change]

**Figure 1. Visual Representation of Posner’s Theory of Conceptual Change**

Instructional strategies that use the theory of conceptual change revolve around writing, discussions or questioning, analogies, and concept mapping. Rarely is drawing used as a tool to evoke conceptual change. However, drawing long has been used to uncover misconceptions (Ballew, 1930; Beilfuss, 2004; Hoese & Casem, 2007; Prokop & Francovlcova, 2006; Sibley, 2005; Tunnicliffe & Reiss, 1999). Limon (2001) states that the best way of instructing for conceptual change is to reveal preconceptions, create conflict and
then encourage accommodation; drawings may be an excellent instructional strategy for this approach. A student who is asked to make a conceptual drawing prior to instruction would be revealing his/her preconceptions. Then, an observational drawing of the same object may create conflict, as the student may begin to see differences between their two drawings.

If educators use student-created drawings as a means to conceptual change, there are two discounted aspects of Posner’s theory that ought to be highlighted. The first aspect is visual perception, and the ability of learners to make (or be guided toward) accurate perceptions rather than misperceptions. Strike and Posner (1992) do briefly attend to a concern about perceptions in their revision of conceptual change, although they focus on the impact that conception has on perceptions. One reason for the deferment of this issue is that most of Posner’s writing on conceptual change focuses on non-visual concepts in physics. So perceptions may come from text or graphs, discussions, etc. The research presented in this study was taken from a biology laboratory, where students directly observe specimens, studying form and function. Visual perception may play a much more important role in this type of course, since students gather a large amount of data from visual cues. The second aspect is cognitive differences between learners – some are more resistant to change than others. Strike and Posner do clearly address this topic as they discuss how misconceptions are resistant to change. However, they do not deal with individual differences in resistance. A depiction of a modified theory of conceptual change includes these two aspects of perceptual abilities and cognitive differences (Figure 2).
Figure 2. Visual Representation of Modified Theory of Conceptual Change
Conceptual Change Theory and Visual Perception

Visual perception is the mental interpretation of visual stimuli. For students new to biology, their “visual difficulties are the result of their inability to visually perceive or appropriately interpret the meaning of biological materials” (Day, 2004). Many students have difficulties in biology classes because they simply do not mentally interpret the fine structures presented. There is strong and abundant evidence to support the importance of visual cues in learning (Dechsri, Jones, & Heikkinen, 1997; Fleming, 1979; Hanson, 2002; Henson, 1996; Mathewson, 1999; Shepard, 1967; Standing, 1973). However, most of this research compares visual information to verbal cues, rather than examining the qualitative interpretation of visual data.

Preconceptions can cause misperceptions, thus making the original conceptions highly resistant to change. For example, Bruner and Postman (1949) showed how preconceptions of a set of playing cards caused misperceptions in what study participants actually saw. The playing cards in the study had been modified so that hearts were black and spades were red. Bruner classified four types of reactions to this visual stimulus: 1) Perceptual denial, where subjects reported the hearts/spades were “normal” colors; 2) Compromise, where the hearts/spades were grayish or purplish; 3) Disruption, where subjects experienced confusion and frustration to the extent that they failed to resolve the perceptual conflict, and 4) Recognition of incongruity.

Langer (1989) addresses similar issues with her research on ‘mindfulness.’ She describes ‘mindlessness’ as an automatic, habitual thought process. Mindful thinking incorporates characteristics of flexibility, novelty-seeking and engagement. She also suggests
that a person with a more mindful approach will perceive more detail in the environment.

Langer’s research includes a scenario where two groups of people are given a dog’s chew toy. One group is told the object “is” a dog’s chew toy; the other group is told the object “could be” a dog’s chew toy. When the groups need to create a new product, the ones with the perception that the object is a dog’s chew toy will not utilize the object for any other purpose. Their preconceptions limit perception and cognitive flexibility regarding the object.

While these examples illustrate how people's perceptions are affected by their preconceptions, students can learn to perceive visual objects without influence through perceptual or observational training. Unfortunately, with no standardized national curriculum for this skill, research and education in perceptual training is scattered. The most prominent and widely-accepted text on perceptual training and drawing education is Betty Edward’s 1979 book “Drawing on the Right Side of the Brain.” Edwards cites five basic skills of drawing; perception of edges, spaces, relationships, light/shadow, and the whole. Clearly, Edwards is focusing her lessons on seeing parts correctly and in a detailed manner. The final basic skill, perception of the whole, acknowledges Gestalt theory. She states that this skill does not need to be taught, but that training to develop the first four skills is essential (Edwards, 1979). These skills exemplify the artists' adage “Draw what you see, not what you THINK you see.”
Conceptual Change Theory and Neurological Variation

There are many cognitive differences that may affect conceptual change. In this study, these differences have been assembled into two groups: 1) brain hemispheric dominance, learning style and/or spatial abilities; 2) religion, conservatism and/or need for closure.

The cognition grouping that includes brain hemispheric lateralization, learning style and/or spatial abilities is limited to visual/verbal learning (a preference or tendency to comprehend information better through pictures, diagrams and demonstrations versus written or spoken explanations) and sequential/global processing (a preference for information delivered in a step-by-step, orderly or outlined approach versus a holistic, “big picture” approach). This limit is due to the substantial disagreement over defining and/or measuring learning styles. However, the visual/verbal and sequential/global tendencies are based on neurological studies of patients with aphasia, physical damage or anatomical asymmetry, or studies using neuroimaging. Localization of function in specific brain structures has been studied since the nineteenth century (Young, 1990). Verbal skills and sequential processing have been associated with the left hemisphere. Visual skills and global, or holistic, processing are associated with the right hemisphere. It is important to address that these skills are not isolated to, but are more strongly associated with, local structures in those hemispheres. Spatial abilities are strongly associated with the right hemisphere. Many tests of neurological damage use perceptual drawing or spatial cognition to check for injuries to the right hemisphere of the brain. For example, visual neglect is usually caused by a stroke in the right parietal lobe. Brain researchers have used functional magnetic resonance imaging (fMRI) to show that brain activity appears to differ between artists and non-artists, with
artists experiencing higher blood flow to the right parietal and right frontal lobes (Bhattacharya & Petsche, 2005; Solso, 2001). Vandenbulcke et al. (2006) found that the right fusiform gyrus is critical in recollection of visual entities. In this study, the three qualities of hemispheric dominance, learning style (visual/verbal and sequential/global) and spatial abilities, will be orchestrated to corroborate data and examine qualitative values of learning styles, without categorizing students in one group or another.

The second cognitive grouping includes religion, conservatism and need for closure. These characteristics have been associated with brain structures, such as the anterior cingulate cortex (ACC). This portion of the brain is involved in conflict monitoring and error detection (Braver et al., 2001; Carter et al., 1998; Yeung et al., 2004). Researchers found a correlation between conservatism and decreased activity levels in this structure, suggesting a lower response for altering behaviors (Amodio, Jost, Master, & Yee, 2007). Other studies have indicated an inversely proportional relationship between religious conviction and neural activity in the ACC (Inzlicht, McGregor, Hirsh, & Nash, 2009). In educational research, Jegede and Okebukola (1991) noted a relationship between observational skills in a science laboratory and the African spiritualism of the students. Some objects from nature were not observed carefully because they were symbolic of evil omens in the traditional cosmological faith of those students. Religion and politics in the United States have also been described as conflicting with cognition in science classrooms, especially with such topics as climate change, genetic engineering, embryonic development, sexuality, and evolution (Cobern, 1994).
It is important to recognize that the correlations between ACC activity and religion or conservatism have not been determined to be a causal relationship. Obviously, religion and political affiliation are sensitive subjects to most people and one must be aware of potential bias in methodology or interpretation of results.

The remainder of this chapter will introduce previous research related to each of the five research questions. Hypotheses were developed based on educational, neurological, social and arts-based research as well as data collected from a pilot study.

**Drawing and Biology Content Knowledge (RQ1)**

Since educational practitioners have debated the importance of drawing in science classes, many researchers have investigated the effectiveness of this tool. However, findings from these research studies often correlate with the cultural bias of the times. It is, therefore, important to understand the shifts in educational use of drawing with respect to historical eras.

During the 1920s to 1930s, the societal push to eliminate drawing from the curriculum led to many studies showing the ineffectiveness of the task (Ayer, 1916; Ballew, 1930; Hunter, 1934; Johnson, 1933; Miller, 1928; Taylor, 1930). During this time period, the Efficiency Movement was strong in the United States, promoting the quantification, timing and analysis of specific processes. Efficiency was paramount in schools which underwent a vast expansion in student enrollment due to immigration, urbanization and child labor laws (DeBoer, 1991; Efland, 1990). Many researchers saw drawing as wasteful of time and an inefficient tool. For example, Miller (1928) explained that students spent over half their lab
periods making drawings. As such, students would see the drawing activity as the most important part of lab, rather than the biological concepts. However, Miller also recognized benefits to drawing, such as providing students with practice in accurately recording information, and learning by direct observation rather than through the teacher’s authority.

Studies compared the use of drawing to other, more technologically-advanced approaches such as photography and mimeographs. These innovations allowed students to label structures on a pre-drawn object, rather than spending the time to create their own drawings. The approach was faster and seemed as effective, or more effective, than the traditional drawings. However, these studies rarely contained statistical analyses and were often quasi-experimental designs. Taylor’s (1930) research did provide empirical evidence that labeling drawings was more effective than student-rendered drawings, but the difference in performance, while statistically significant, was only 4% to 5.5%. This is hardly a strong difference especially when one considers that the “mental abilities” of labeling group were ranked as higher. Similar studies reported similar conclusions, although there were no data presented (Alpern, 1936; Ballew, 1931). While all of these studies promoted labeling as more time-efficient, they beg the question, what happened during the remainder of lab when there was more time available? Could this variable have contributed to the difference between the two groups?

The end of this era, prior to World War II, resulted in conflict between educational philosophy and the general societal philosophy. While many research studies indicated ways of increasing efficiency in classroom activities, another educational movement began in the Chicago School. Philosopher and educator John Dewey proposed that efficiency and “the
factory system” applied by schools to their classes were ineffectual for student learning (Dewey, 1938). Student interests and experiences increased engagement, and multidisciplinary topics that related to the real world were preferable. While Dewey was clearly opposed to the way drawing was taught at this time, “as if the accumulation of observed facts and the acquisition of skill in manipulation were educational ends in themselves” (p192), he was a proponent of students discovering function by closely observing structures (Dewey, 1910). It is important to recognize that Dewey’s admonition of drawing in school was due to the way drawing was taught according to the geometric approach. The style had been proposed in the mid-1800s, and apparently was still widely-utilized in the school systems.

From the 1960s to 1980s, there appeared to be a shift back to a positive view toward drawing as a learning tool in the educational system. This shift may be the result of three factors: 1) the influence of Piaget on constructivist learning; 2) visual learning research; and 3) proponents of multiple learning styles.

Piaget’s influence spanned disciplines of psychology, education and philosophy. He was largely influential in the creation of the constructivist learning approach – that the learner has certain background information, or schema, and must assimilate new information into that schema or accommodate by creating a new schema. In other words, the learner must construct the knowledge in their own mind. If assimilation and accommodation are imbalanced, there is disequilibrium or “cognitive conflict” (Wadsworth, 1979).

Visual learning research in education expanded when printing technology advanced, allowing more graphics and images to be used in textbooks. The size and number of color
photographs and computer-drawn graphics increased substantially throughout the 1970s and 1980s (Blystone & Barnard, 1988; Carney & Levin, 2002). As a result, many researchers started looking into the effectiveness of these graphics on student learning. Psychological research into pictorial recognition memory, as well as comparisons between visual and verbal learning, led to a positive view of visual communication (Fleming, 1979).

The concept of “learning styles” grew from this comparison between visual and verbal learning, gaining popularity in the 1970s and 1980s. Kolb, Gregorc, and Gardner were three of most prominent proponents of learning styles. Many neuroscientists and educational researchers have criticized learning styles as lacking reliability, validity, or empirical evidence. They argue that knowledge of learning style may not be helpful to educational goals (Curry, 1990; Sewall, 1986; Stahl, 1999). However, the concept of learning styles remains popular.

Since the late 1990’s, more educational researchers and practitioners have been examining the use of drawing in the classroom. These studies often are not controlled though, and make claims that are not supported by the data (Eisner, 1998). Many are geared toward the use of drawing as: 1) an evaluation tool; 2) an alternative or aid to research interviews or; 3) a general review of perceived benefits of drawing in the classroom, rather than an examination of drawing as an educational tool (Alkaslassy & O'Day, 2002; Bland, 2004; Gallas, 1991; Hanson, 2002; Hayes, Symington, & Martin, 1994).

Though many research studies were conducted throughout these cultural shifts, no conclusive link has been found between drawing and learning. As addressed above, most of the recent studies of drawing are qualitative with diverse or undefined variables. Eisner
(1998) reviewed other studies that examined the impact of arts as they relate to academic achievement. He laments that while many researchers claim the positive effect of arts on academics, there is no empirical evidence to support that conclusion.

In one study by Alkaslassy & O’Day (2002), students who used drawing in the classroom actually performed worse on knowledge-based tests, although the treatment groups were not selected at random and there were no pre-tests to check for differences in content knowledge among the groups. Hanson (2002) showed that drawing was associated with improvement in learning, but had no control group in the study. Interestingly, most of the quantitative research with controlled variables is found in the medical field – with the results that medical professionals who engage in arts (observation) training improve their diagnostic abilities (Elder, 2006; Kirklin et al., 2007; Lindquist, 2008; Rodenhauser et al., 2004; Shapiro, 2006).

Most of this empirical evidence from the medical community focuses on how high-level training in observing fine art translates into improved observation in a diagnostic setting. This involves the transfer of observational skills from one task to another. The isolation of skills may be a key element to drawing-in-education research. Drawing, in itself, may not be the learning tool; it may be the observation, attention to detail, and recording or acknowledgement of those observations. The two skills, drawing and observation, are difficult to isolate when researching the effects of drawing.

Some researchers have studied drawing as a conceptual tool, where no observational skills are used. The drawings are used as a “problem-solving strategy” for students. For example, Gobert and Clement (1999) had students read a passage on plate tectonics. Then,
either students drew a diagram about the passage, wrote a summary, or just read the text (control group). The group that drew a diagram significantly outperformed the other groups in comprehension of the material.

A similar study compared fifth graders who constructed either drawings or written descriptions of a map before listening to a story about events which occurred in locations delineated on the map. There were no statistical differences between groups in the amount of information recalled from a story (Kulhavy, Lee, & Caterino, 1985).

Others, such as Snowman and Cunningham (1975) and Van Meter et al. (2001), used analytic drawings to support learning from a passage of text. In both studies, drawing increased knowledge acquisition. They concluded that readers constructing drawings engaged in more self-monitoring events, or detected more comprehension errors, than did readers not constructing drawings (Van Meter, 2001). While training in advanced observational skills may force attention to detail and correction of visual misperceptions, the act of creating a drawing may force students to detect and confront conceptual errors.

Hypothesis: Students who engage in drawing as a learning tool will demonstrate slightly higher levels of biological understanding than students exposed to alternative learning tools.

**Difficulties with Studying Drawing as a Learning Tool**

There are many challenges in examining drawing as a learning tool. First, there are different types of drawing. Much was written about representational (life-like) and analytical (interpreted) drawings during the early 20th century (Ballew, 1931; Hunter, 1934; Johnson,
1933). However, the literature rarely addresses another division of drawing, based on how the product is created: observational (or perceptual) and conceptual drawing (Fish & Scrivener, 1990). Perceptual drawing occurs when the drawer is viewing the object while s/he creates the drawing; the drawer uses visual evidences to lead to the drawing’s conclusions. Conceptual drawing is the production of a drawing from mental visualization, and uses imaginary or preconceived notions to create the drawing. Usually, perceptual and representational drawings are related, while conceptual drawing is associated with analytical graphics. However, these terms differ when examining how the drawing is made versus the categorization of the final product.

Second, drawing is difficult to study scientifically due to the multiple uses of drawings. In some cases, the students use their drawings toward learning goals. In other cases, drawings are used for non-educational purposes, such as to provide a mental break for students, to aid in classroom management, to promote creativity, to check for understanding or pre-conception, or to assign participation grades. In research, the purpose of the drawing must be clear to the students, instructor, and researcher.

Third, students have different levels of practice or experience with drawing. Some have been taught how to make observational drawings, including ‘tricks’ used by artists to check for accuracy in form. Others have experience only in conceptual drawing, or little drawing experience at all. These differences in skills training or education should be acknowledged in the research.

The fourth difficulty in the research of drawing as a learning tool is the measurement of outcomes from the drawing. Many studies examine total knowledge acquisition as a
quantitative approach. While this is the overall goal of using drawing, there are many other variables in learning, and it is difficult to attribute gains to the drawing alone. Other studies examine the educational outcomes of drawing qualitatively. In general, these studies extol the benefits of drawing activities as a means to increase interaction between student and teacher, counter misconceptions, improve sophistication of questions, develop perception, and link observations to behavioral and ecological understanding (Day, 2004; Gallas, 1991; Hoese & Casem, 2007; Matern & Feliciano, 2000). The question remains that if drawing activities are the bases for these huge educational gains, why do we not see the same leaps in understanding when analyzing quantitative data?

Finally, some students may have a predisposition to observing and drawing. They may enjoy the process more than other students, or have genetic or environmental influences, which allow them to study more, practice more, or perform at a higher level. While this issue may be controversial, we do know that every student is unique, and assorted approaches to learning may benefit different students. It should be acknowledged that some students may have better outcomes using observational drawings than others. At present, no studies on drawing have examined this phenomenon, although many critics of drawing in the 1920s-30s described the disadvantaged students who were less adept drawers (Ballew, 1930; Miller, 1928).

**Drawing and Attitude Toward Biology (RQ2)**

Many educational researchers have raised concerns about the decline of students' attitude toward science (Barmby, Kind, & Jones, 2008; Osborne, Simon, & Collins, 2003;
Prokop, Prokop, & Tunnicliffe, 2007; Ramsden, 1998; Schell, McCroskery, Gooding, Swift, & Swift, 1987). In general, students in elementary school have very positive attitudes toward science, but by the time these students reach high school, their attitudes have deteriorated. This decline is more pronounced in females. Interestingly, student attitudes toward science can decline over the course of just one school year (Schell et al., 1987). Reasons cited by students for their weakening interest in science are few hands-on activities, poor teaching practices, difficulty level, and irrelevance of the subject (Barmby et al., 2008; Delpech, 2002; Osborne et al., 2003; Prokop et al., 2007).

The term 'attitude' can be approached from emotional, behavioral, or cognitive views. Emotional and behavioral attitudes in this study are characterized by the student's self-description of enjoyment of biological topics and willingness to become involved with biological pursuits. Cognitive attitude includes a student's self-concept of biological knowledge or capabilities, as well as the perceived value of biology to society.

Attitude is often linked with classroom performance. However, this relationship is a correlation, not a causal relationship. A student with a positive attitude toward biology does not earn good grades or understand the material because of their attitude. However, according to Bandura (1997), people with higher self-efficacy, one aspect of attitude, exhibit longer persistence and perform better than those with low self-efficacy. Attitude often is associated with interest and attention, motivation, and cognitive engagement.

The impact of drawing activities on the enjoyment of another subject, such as biology, has not been quantitatively addressed by researchers. However, some have investigated student attitudes toward drawing activities, in general. The majority of studies in
which drawing is used in science classes indicate that the students enjoy the activity or see
the activity as positively affecting their performance in class (Alkaslassy & O'Day, 2002;
Bland, 2004; Hanson, 2002; Hayes et al., 1994; Matern & Feliciano, 2000).

Hypothesis: These studies suggest that students who experience drawing as a learning
tool will demonstrate more positive attitudes toward biology than students who use
alternative learning tools.

Drawing and Observational Skills (RQ3)

Drawing in the science classroom is used to collect and record visual data,
communicate findings, and focus attention on fine details of a specimen. But is drawing an
effective method to improve observational skills? There is a pervasive belief that drawing
forces students to focus on a subject and look closely, and to slow down and spend time
observing behaviors, movements, or structures that they would not see otherwise (Adams,
2002; Bland, 2004; Coates, 1984; Dempsey & Betz, 2001; Nelson, Martin, & Baldwin,
1998). However, there is limited quantitative research investigating this question because of
the difficulty in measuring these advanced observational skills.

Most observational skills examined in educational research are associated with
elementary process skills for young children. These basic skills include differentiation
between colors, textures, and basic measurements (Southwest Educational Development
Laboratory, 1996). While these observations may be measured in general terms, it is far more
delicate and difficult to measure advanced observational skills (Eberbach & Crowley, 2009).
The ability to accurately perceive visual information has been extensively examined by Gestalt theorists. Gestalt theory describes how the mind perceives visual cues and processes them according to a type of grouping (Smith, 1988). Examples of these mental perceptions include inferring or constructing a shape from its parts, finding patterns, or ‘flipping’ back-and-forth between multiple interpretations of the same image (see examples in Figure 3).

![Figure 3. Examples of Gestalt visual processing (from Smith, 1988)](image)

This automatic mental processing can lead the mind to misinterpret visual cues when it does not understand an object, which is the basis for optical illusions and perception puzzles. Just as one can see different objects in the same image, a student can look at the same visual stimulus (such as a dissected organism or a microscope slide) and perceive a different object than that to which the teacher is referring.

Observational skills can be improved by drawing. Van Sommers (1984) found that if subjects draw the components of an object, rather than the whole object, the resulting
drawing is more accurate. By creating a drawing, one can isolate the parts and correct the optical illusions described by the Gestalt Laws. Neurological studies have shown that with practice, subjects can develop a more fine-tuned ability to discriminate visual stimuli and can overcome Gestalt perceptual errors (Thiele, 2004).

Observations can also be altered by an individual's mental processes. For instance, in constructed perception, people see what they want or expect to see (e.g. in a darkened house, one may reach down to pet a dog but realize it’s a footstool). When drawing, people will draw images differently if they are told the object has different meanings (Van Sommers, 1984). In directed perception, one receives visual stimuli and then makes the perception from those data. This is a more scientific approach to perception, as the visual data direct the conclusions rather than the reverse. Directed perception is the goal of an observational drawing.

Unfortunately, assessments of observational skills are limited to Gestalt perceptual illusions, basic observational skills promoted in elementary schools, or neurological tests designed to assess damage (e.g. Test of Science Process Skills, Techniques for Assessing Practical Skills, Bender-Gestalt test, Draw-a-Clock test, Visual Pattern Completion Test, Visual Design Reproduction Test, Block Design section of the WAIS). Other observational skills tests used in science or biology require knowledge of the topic, requiring the utilization of observations rather than just the observations themselves (Hungerford & Miles, 1969; Jegede & Okebukola, 1991). Many of these tests have a significant qualitative component to analyze the observational skills of the student. For these reasons, an Observational Skills Assessment was developed for this study (Landin, 2010).
If drawing can increase attention and accuracy of perception, will that now translate to an increase in learning or cognitive change? Clearly, attention is required for learning. If a student does not pay attention, s/he will not be able to encode the information for future use. Eye-contact is often used as an indicator of attention, with a correlation between achievement and eye-contact (Piontkowski & Calfee, 1979). However, looking at an object does not guarantee attention, as demonstrated by inattention blindness studies (Mack & Rock, 1999; Simons & Chabris, 1999).

Misperceptions (or inaccurate perceptions) may be a significant factor in observation research. Cohen and Bennett (1997) tested four experimental conditions to explain why people produce inaccurate drawings. These conditions included misperception of the object, insufficient motor skills, misperception of their own drawings, and the inability to determine which information should be included in their drawings (lacking “representational decision-making abilities”). Their data concluded that misperceiving the object was the most prominent reason for inaccuracies in drawing.

Hypothesis: These studies suggest that students who use drawing as a learning tool, especially those who receive instruction in how to draw, will demonstrate more sophisticated observational skills than students who use to alternative learning tools.

Student Perceptions of Drawing Activities (RQ4)

Student and teacher perceptions of drawing activities generally are positive. Bland (2004) wrote that 89% of college-level respondents to his survey indicated that drawing is a valuable tool in biology classes. Interestingly, females, freshmen and general education
students had a more positive perception of drawing than males and biology majors. In a survey of instructors, the most common reasons for requiring students to draw were that the activity "causes students to look more closely" and "causes students to focus on details."

Even in the 1920s-1930s when drawing was being removed from biology classes, the overall perception of the activity seemed positive. Many sources describe drawing as a valuable tool for remembering, encouraging investigation and originality, seeing more detail, accurately recording information, concentrating, uncovering student misconceptions, and linking form to function (Ballew, 1930; Fitz, 1897; Johnson, 1933; Miller, 1928).

Experiments into the effectiveness of drawing as a learning tool did not address these perceptions. They focused on time spent drawing, often comparing drawing to labeling mimeographed images. While drawing had been dismissed due to time constraints and a need for efficiency in the classroom, it seems that drawing was still positively viewed as a learning tool.

At present, teachers and students have a strongly positive perception of drawing activities. This may be the result of new knowledge regarding visual cognition, or from the social acceptance of ideas like Gardner's multiple intelligences or Kolb’s or Gregorc’s Learning Styles. Bloom’s Taxonomy also supports drawing activities, especially when compared to a labeling activity, since labeling is a Level 1 (Knowledge) action whereas the creation of a drawing is a Level 3 (Application) or even Level 5 (Synthesis) action. Perhaps the current positive perception of drawing is due to the rare use of drawing as a learning tool. The task is different or unusual, which may make it more appealing to teachers or students.
Hypothesis: Research suggests that students who draw will express more positive perceptions toward the activity than students assigned to alternative methods.

Conceptual Change and Individual Cognitive Processes (RQ5)

Originally, this research question revolved around hemispheric dominance. Ballew (1930) addressed concerns about the advantages of artistic students, but this concern was not based on any empirical evidence. The question, however, was intriguing; if some students are more visually-dominant, would they excel at learning through drawing? Would verbally-dominant students be disadvantaged?

Drawing, spatial abilities, and visual tasks are associated with the right hemisphere of the brain, which processes information in a holistic, non-linear order. Language, speech, reading and verbal tasks are generally in the realm of the left hemisphere, which processes information temporally or sequentially (Bradshaw & Nettleton, 1983). If students exhibit higher functioning in one hemisphere, then tasks that are based in that hemisphere may be more enjoyable and easier to complete or comprehend.

The second aspect of this research question, conservatism and religion, arose from observations made during the first phase of this study, as Research Questions 1-4 were examined. I observed some students paying close attention to specimens, spending large amounts of time and energy in order to complete their assignments in an accurate and detailed manner. Other students took one quick glance at the specimen, returned to their seats and then started their assignment. While I knew different students would produce drawings at various levels of quality and detail, I had assumed that drawings would have to be made
while observing the object. The group of students who did not observe the object while making their drawing or description caught my attention. I considered what cognitive factors could explain this difference in behavior between the two groups.

Genetic, environmental or developmental factors influence structures of the brain, affecting how information is perceived and processed. Since this study is centered on perception of detail and the ability to produce conceptual change, I reviewed studies on error detection and cognitive closure. Many of these studies addressed differences in these characteristics between liberal and conservative leanings, and religious and non-religious beliefs (Amodio, Jost, Master, & Yee, 2007; Dollinger, 2007; Inzlicht, McGregor, Hirsh, & Nash, 2009; Jost, 2006; Kruglanski, Webster, & Klem, 1993; Nyborg, 2009; Oxley et al., 2008; Tetlock, 1983; Webster & Kruglanski, 1994). In general, people who claim to be either more conservative or more religious exhibit a more structured, persistent cognitive style. People who identify themselves as either liberal or less religious are more responsive to novelty and ambiguity, thus demonstrating more cognitive flexibility.

The focus of my interest is the acceptance or rejection of new information, as learners must be able to accept novel information in order for cognitive change to occur. Those students who accept new information can adapt cognitive constructs. Students who reject new information maintain consistency in preconceptions. In order to reject new information, the student must be able to ignore any detection of cognitive conflict.

Since a neural structure, the anterior cingulate cortex (ACC), is active during moments of error, it has been used in detection of cognitive conflict (Braver et al., 2001; Yeung et al., 2004). In a study by Inzlicht (2009), the ACC showed reduced activity in
people with strong religious zeal and greater belief in God. When Amodio (2007) compared liberals and conservatives, they found decreased ACC activity in conservatives.

I must reiterate that the correlations discussed between cognitive conflict and political or religious affiliations are correlations only, not causes. This aspect of the research is intended to collect data as a starting point for future research. As this research question is informational in scope, no hypothesis has been developed.

Summary

With these five research questions, I intend to add empirical evidence to an educational approach which has been based more on educator perception than on data. Drawing as a learning tool has been scorned or embraced throughout history, its effectiveness described mostly by opinion or by factors other than the effectiveness of the task as a means for learning. This study will examine, both quantitatively and qualitatively, the relationships between the use of weekly drawing activities and changes in content knowledge, attitude toward biology, and observational skills.
CHAPTER 3: METHODS

This research was divided into two parts: Study One) a larger-scale mixed-methods study to investigate the use of drawing as a teaching tool, based on similar studies by Gobert & Clement (1999) and Van Meter (2001); and Study Two) a small-scale study examining cognitive factors that may affect conceptual change.

A pilot study preceded Study One to prepare and test drawing activities and measurement tools. It was also used to obtain feedback from students on perceptions of the drawing activities and statistical analysis of assessments. This information was used to create a survey, adjust drawing activities, improve pre- and post-tests, and gather preliminary data.

Pilot Study

The pilot study was conducted at a large urban university in the southeastern U.S. in the fall of 2008. Participants were enrolled in an undergraduate non-majors biology laboratory associated with an introductory biology lecture course. Forty-eight students were enrolled, most of whom were freshmen representing a wide variety of majors (e.g., education, international studies, criminology, business, etc.). Two labs, each with 24 students, were identical in activities, location and materials, instructor, and length of time. The first lab section was selected to receive the drawing treatment at random prior to the first meeting. The second lab section was assigned the writing treatment. Students participated in the study for a 10-week period (10 lab sessions).
Pilot Study - Research Design and Methods

Each laboratory section completed in-class assignments that included either written or
drawn descriptions of biological structures, concepts or organisms. Questions on weekly lab
activity sheets were the same, with the exception of the verb “Draw” or “Write”/ “Describe.”
The assignments were collected at the end of lab. Students did not receive grades or
comments on these assignments.

Students took a series of pre- and post-tests to measure content knowledge, attitude
toward biology, and observational skills. Student t-tests were used to statistically analyze the
pre- and post- differences in scores and confidence intervals were used to compare between
the two groups. Students in Laboratory One (drawing treatment) participated in a focus
group, and two of those students were individually interviewed about their drawing
assignments.

Pilot Study – Testing and Activity Analysis

The three assessments (content knowledge, attitude toward biology, and observational
skills) were examined for reliability and validity. The test for content knowledge was based
on material covered in the lecture/lab course and was analyzed for question difficulty and
discrimination. The attitude toward biology assessment was based on the Attitude Toward
Science Inventory (Gogolin & Swartz, 1992). This adaptation of the likert-scale test was
examined for split-test reliability. The observational skills assessment (OSA) was developed
specifically for this study as no other test for quantifying advanced perceptual abilities could
be found. The development of the OSA is described in detail in Landin (2010); basic reliability and validity claims are presented below.

The test for content knowledge consisted of 46 questions. Difficulty ranged from 5-97% in the pre-test and 13-100% in the post-test. A difficulty range of 30-80% was desired, so questions outside of this range were adapted or replaced. The discrimination indices varied between -0.07 and 0.71. Questions with discrimination indices below 0.25 were adapted or replaced. Overall, 18 of the original questions met both the difficulty and discrimination requirements.

A comparison of student scores on the pre- and post-test indicates a correlation of 0.703. The post-test scores show an average increase of 26.6%. Pre- and post-tests were compared using a Participant Code, known only to the student. While a correlation between post-test scores and overall course grades would have been helpful to analyze the validity of the test, individual student performance could not be matched to this test due to concerns of student anonymity.

One question was included in the knowledge test as a negative control. The content of the question was not addressed during the semester-long course. Pre-/post test raw scores were 35% and 37% respectively. Two other questions of similar pre- or post-difficulty levels had raw scores of 26%/35% (pre/post) and 37%/67% (pre/post). While one negative control question is a very small sample, the data do support the validity of this test.

Attitude toward biology was measured using an adapted Attitude Toward Science Inventory (ATSI), a self-response likert scale assessment. The ATSI focuses on six subdivisions of attitude. For the adapted inventory used in this study, I substituted the word
"Biology" for "Science" and focused on three of the six subdivisions (enjoyment, self-concept, and value to society). Based on a split-half reliability test, this modified ATSI has a reliability of 0.79.

Observational skills were the most difficult to measure. An assessment, the Observational Skills Assessment (OSA), was developed to quantitatively measure observational skills. Grading reliability for the test is strong over time (98%) and between graders (71-90%). While validity is difficult to ascertain, comparisons with qualitative rankings were 71% within one point and 95% within two points. Correlation between the OSA and self-reported drawing experience is positive 0.67. Since many professional artists, art instructors, as well as cognitive researchers consider drawing ability closely related to skills in visual perception, this score supports the validity of this test (Bhattacharya & Petsche, 2005; Cohen, 2005; Cohen & Bennett, 1997; Eberbach & Crowley, 2009; Edwards, 1979; Frith & Law, 1995; Kozbelt, 2001; Miall & Tchalenko, 2001; Solso, 2001; Tchalenko, 2009; Van Sommers, 1984; Weekes, 2005).

Finally, the interviews and focus group were conducted to establish a qualitative understanding of student impressions of the activities. These qualitative assessments also helped in the development of a survey, and in assessing the quality of the worksheet activities.

Pilot Study – Results and Conclusions

According to pre-tests, there was no difference between the two lab groups in knowledge, attitude, or observational skills prior to the pilot study. After treatment, the
laboratory section that had drawing assignments showed a significantly higher increase in knowledge and observational skills. There was no significant difference between the two treatments in attitude toward biology (Table 1).

Table 1. Results from Pilot Study Pre-/Post-tests (Knowledge, Attitude, and Observational Skills)

<table>
<thead>
<tr>
<th></th>
<th>Writing Lab</th>
<th>Drawing Lab</th>
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</thead>
<tbody>
<tr>
<td>Knowledge</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-test</td>
<td>44%</td>
<td>43%</td>
</tr>
<tr>
<td>Post-test</td>
<td>69%</td>
<td>75% *</td>
</tr>
<tr>
<td>Attitude (9% positive response out of total possible)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-test</td>
<td>42.6%</td>
<td>47.2%</td>
</tr>
<tr>
<td>Post-test</td>
<td>51.0%</td>
<td>55.4%</td>
</tr>
<tr>
<td>Observation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-test</td>
<td>44%</td>
<td>42%</td>
</tr>
<tr>
<td>Post-test</td>
<td>43%</td>
<td>51% *</td>
</tr>
</tbody>
</table>

According to the focus group and interviews, students presented generally positive feedback about the drawing activities. Most students valued the drawing as a way to improve observation, memory, or learning, stating that drawing was “more memorable” and helped them to “see the detail and intricacies” of the subject matter. Some students expressed negative opinions, though these students still valued the drawing. For example, one student stated, “Well, I, like, hate drawing ‘cause I’m so bad at it. But, then it’s like, you know how when you do stuff that is like a challenge for you, you remember it more?” Another student responded, “Um, I don’t really like drawing, but I learn better by looking at pictures. So I guess if I draw something rather than writing it out in words, I would understand it a little better.” One student discussed using images to recall laboratory activities: “if you look back over your drawings, you can see what actually took place. It is a lot easier to have an image than words explaining.”
One of the interviewed students, who had been involved with an extracurricular art group in high school, stated “I kind of feel, like, bad handing in something that doesn’t look good, because I’m into art”. She felt that the short time allotted for the drawing activity did not allow her to create a finished drawing of which she could be proud.

Both the interviewed students and those in the focus group expressed a frustration with drawing assignments that related to concepts (conceptual drawing), rather than direct observations (perceptual drawing). One student summarized her opinion by stating:

I think not every lab should have drawing, because some of them – it just doesn’t really pertain…But this last one with the skulls and one where we looked up bacteria through a microscope, I think those are really important and the drawing should stay.

Conclusions from this pilot study mirror previous research on the topic of knowledge gain. The drawing group indicated more improvement in knowledge, as well as in observational skills, supporting drawing as a cause of the knowledge gain. While attitude toward biology improved over the course of the semester, the gain was not significantly different between the two groups. Finally, perceptions of drawing activities are positive, with most students either enjoying the activity or recognizing that the drawings force them to look more closely and pay more attention to subjects.

Studies that examine conceptual drawing (Gobert & Clement, 1999; Van Meter, 2001) indicate the same positive perceptions and increase in comprehension of material. Students in this course did not seem to understand the cognitive purpose of the conceptual drawings. Since my research examines perceptual skills, I did not further address this issue. All conceptual assignments were replaced for Study One.
Problems that surfaced during the pilot study were similar to problems seen in similar research. Drawing goals should be clearly defined; in this case, the focus is on perceptual drawing rather than conceptual drawing. Most importantly, treatments should be assigned randomly to individual students rather than by class. Lastly, some students should be presented with guidelines on how to observe and draw in order to examine the impact of teaching observational skills.

Study One

This research is a modified version of the pilot study. The main goals of this study are to provide empirical evidence relating to perceptual drawing as a learning tool, examine the qualitative and quantitative differences between those using drawing activities and those using writing activities, examine the effects of instruction in drawing compared to non-instruction, and gain perspective on the participants’ perceptions of the activities.

The research questions addressed during Part One of the study are:

- Do students who participate in weekly drawing activities demonstrate a higher level of biology content knowledge when compared to students who instead participate in weekly writing activities?
- Do students who participate in weekly drawing activities show a more positive attitude toward biology when compared to students who instead participate in weekly writing activities?
• Do students who participate in weekly drawing activities display improved observational skills when compared to students who instead participate in weekly writing activities?

• What are student perceptions of drawing activities in relation to biological understanding?

Study One – Research Design

All participants completed workbook activities associated with their laboratory assignments. While all workbook activities request the same information from each student, they were asked to provide that information in one of three different ways. Each study participant was randomly sorted into the Writing Group, Drawing Group, or Drawing with Instruction Group. The Writing Group was asked to submit written descriptions of organisms or structures. The Drawing Group was asked to submit labeled visual descriptions (drawings) of organisms or structures. The Drawing with Instruction Group had the same assignment as the Drawing Group, but were presented with a 10 minute how-to-draw lecture at the beginning of the semester. This group also received feedback related to their drawing techniques for each assignment. The drawing instruction was based on Betty Edwards’ (1979) approach to drawing. Feedback on student-generated renderings included reminders from the how-to-draw lecture and suggestions for improving their next drawing.

Based on pilot study data, individual students were randomly assigned to one of the three groups before the laboratory course began. Each of the ten workbook activities was based on perception/observation of material objects only; no conceptualization was required
of the students. Also, the workbooks contained all ten assignments, allowing students to review their progress over time and use the workbook to re-examine their assignments and the topics covered.

The participants attended twelve laboratories throughout the semester; ten of those had corresponding workbook activities. Two of the six weekly laboratory sections were observed by the researcher during those activities when students were completing their workbook assignments. The observer could not see which treatment group was assigned to a student, only the student’s behavior. At the conclusion of the study, the researcher matched the observation records to individual students whenever possible.

Participants took pre- and post-tests on content knowledge, attitude toward biology, and observational skills. Students also supplied demographic information at the beginning of the semester, and a completed survey of opinions of the laboratory workbook assignments at the end of the semester. Interviews of a few students were requested and occurred at the end of the semester, after the conclusion of the course. A visual representation of the timeline of tests and activities for Study One can be found in Figure 4.
Study One – Study Participants

The study participants included 141 freshman biology majors, all 18 years of age or older. The study was conducted during a spring semester, when only one introductory biology course is offered to these students. As a result, all study participants received the same lecture material, presented by the same instructor.

Laboratories were limited to 24 students. There were six lab sections corresponding with the lecture course; every student was required to enroll in a lab section. The six labs were taught by three teaching assistants (TA), two lab sections per TA. Each TA taught these same laboratories over the previous semester so they had the same amount of experience with the laboratory exercises.
Study One – Materials

The Laboratory Course is a hands-on, specimen-rich class. Students had laboratory assignments associated with their lab manual, as well as the single weekly assignment for their Lab Workbook. The Lab Workbooks were printed on standard letter-size printer paper and folded so each assignment was a half-sheet in size.

The Writing Group workbooks contained assignments that required the student to write out a description of their observation (eg. “Write a detailed description of one skull (bird or mammal) from the collection. Include any attributes (bones, structures, characteristics) that you can identify.”). The Drawing Group workbooks contained assignments that required the student to draw what they observe and label structures (eg. “Draw one skull (bird or mammal) from the collection. Label any attributes (bones, structures, characteristics) that you can identify.”). The workbook for the Drawing with Instruction Group contained the same assignments as the Drawing booklet with an additional statement “Remember SHAPE, DETAIL and SHADING” written after each assignment. This statement refers to the short drawing instruction these students received on the first day of lab. The inside front cover of their Lab Workbook also contained a reminder of drawing techniques presented to them during that instructional period.

Study One – Instrumentation and Scoring

Students completed pre- and post-tests on the first day of lecture (for Content & Attitude tests) and lab (Observational Skills Assessment), and on the last day of lecture and lab. Participants filled out the survey on the last day of lab. Interviews were conducted after
the completion of the lab course. Surveys addressed student perceptions of the drawing or writing assignments, and the interviews delved further into details and origins of these perceptions.

The Content test is based on material covered in this General Biology course (Appendix A). Questions had a range of difficulty values from 28% to 100% and point discrimination index (below 80% difficulty) ranging from 0.36 to 0.68.

The Attitude test was based on the published Attitudes Toward Science Inventory (Gogolin & Swartz, 1992). The assessment was slightly altered by limiting questions and substituting the word “Biology” for “Science” (Appendix B). The modified test was examined for reliability between questions, as described in the pilot study test analysis above.

The Observational Skills Assessment (OSA) is a test designed and analyzed by the author (Landin, 2010). It involves the test-taker observing and drawing a selection of common objects, lollipops in a mason jar (Figure 5). Each drawing is evaluated for the presence of general and specific details and proportions to quantify the test-taker’s observational skill level.
The student survey, given during the final lab, included questions about the student’s experience with their workbook assignments (Appendix C). Interviewees were selected based on their treatment group and depth of description on the survey. Surveys and interviews were coded based on responses provided by students (Appendix D). Inter-rater reliability on this coding structure was 81%.

Interviews started with questions about students' recollections of topics and activities covered in lab – either from their lab manual or from their workbook. Then students were asked for clarification of survey responses, experience and personal recollections, or opinions of the workbook activities.

Observations made while students completed their workbook activities were examined for behavioral similarities or differences between assigned groups. These qualitative data, such as student looking behaviors, drawing behaviors or social behaviors, were recorded in a...
notebook during these observations. I identified students by seating location, since I did not know their names or to which treatment group they were assigned. At the end of the semester, TAs filled out seating charts so I could match the recorded behaviors to the students’ Lab Workbooks.

*Study One – Statistical Analysis*

Statistical differences between the three treatment groups were analyzed using confidence intervals of student performance on the tests for knowledge, attitude, and observational skills. Qualitative analysis included drawings, surveys and behavioral observations made by the researcher. Drawings were assessed on detail and accuracy; student comments on the surveys were coded for common themes; and observational notes were examined for recurrent student behaviors.

**Study Two**

The second study was designed to examine cognitive factors, unique to each student, which may influence their learning from drawing applications. The cognitive factors addressed include general learning style (verbal/visual or sequential/global), hemispheric dominance and spatial ability, as well as conservatism, religiosity and need for closure.

The research question addressed in Part Two of the study is:

- Are there correlations between content knowledge gains related to drawing activities and student cognitive processes?
Study Two – Research Design

In this study, every participant completed identical workbook activities associated with laboratory assignments. They were given a 10 minute how-to-draw lecture after the third laboratory – enough time for them to struggle, or become dissatisfied, with their drawing assignments. They also received feedback on their drawings for each assignment (similar to the Drawing with Instruction group from Study Part One). The participants had twelve laboratories throughout the semester, ten of those with corresponding workbook activities.

Participants took pre- and post-tests on content knowledge, attitude toward biology, and observational skills. Students also completed a form of demographic information at the beginning of the semester, as well as a survey of their views about laboratory workbook assignments at the end of the semester. Interviews of a few students were requested and carried out at the end of the semester, upon completion of the course.

Since all of these students have the same treatment, the difference between them is student cognitive approaches, such as hemispheric dominance and conservatism. This study examined whether there was correlation between these cognitive differences and changes in knowledge, attitude, observational skills, or perceptions when using drawing as a learning tool.

Study Two – Study Participants

The study participants included 44 freshman non-biology majors, all of whom were 18-21 years of age. All study participants received the same lecture and lab material, presented by the same instructor. The class was divided into two laboratory sections of 22 students.
each. Each laboratory section was taught by the same instructor, in the same location and with identical activities.

Study Two– Materials

Students were given identical Lab Workbook assignments for each of ten laboratories over the course of the semester. Lab Workbooks were printed on folded standard letter-size printer paper; two drawings were made on the left side of the Workbook and questions pertaining to the drawings were answered on the right side of the Workbook. Each assignment included one drawing of the student’s preconception completed before the activity, and one perceptual drawing made while the student had observational access to the subject material. Each assignment also included questions about comparing structures or form-and-function of structures.

Study Two – Instrumentation and Scoring

Pre-tests (for knowledge, attitude and observational skills) and cognition tests (for hemispheric dominance and conservatism) were given to every student at the start of the semester. Due to the amount of time required for these tests, knowledge and attitude tests were given on the first day of class, cognition tests were given the following week, and the OSA was administered on the first day of lab.

Post-tests for knowledge were incorporated into Unit Exams. The post-OSA, post-attitude and a survey of student perceptions (similar to the survey from Part One; see Appendices A-D) were given to students on the last day of lab. Interviews were conducted after the completion of the course.
The Knowledge test, Attitude test, and Observational skills test are the same as those described in Study One. The cognition tests are based on published assessments:

- Hemispheric dominance (Appendices E-G): Hemispheric Dominance Inventory, Index of Learning Styles (Soloman & Felder, 2009), and Mental Rotation test
- Conservatism (Appendices H-J): Need for Closure Scale (Webster & Kruglanski, 1994), the Wilson-Patterson Issue Battery (Henningham, 1996; Wilson & Patterson, 1968), and Religious Conviction and Political Conservativism (Inzlicht et al., 2009)

*Study Two– Statistical Analysis*

Statistical comparisons were made using correlation analysis. Variables included the amount of change in performance on the knowledge test, attitude test, and the OSA. Since the treatment (drawing) was the same for all students, correlations were examined by scores on hemispheric dominance or conservatism tests.

Student surveys and interviews were coded for common themes and analyzed quantitatively and qualitatively (codes in Appendix D). Drawings were examined qualitatively for detail and accuracy, and compared to pre-conceptual drawings for similarities.
CHAPTER 4: RESULTS

In this section, I report the results of two research studies: one large-scale study comparing students who use weekly drawing activities to those using weekly writing activities; and one smaller study examining any relationships between student cognitive differences and conceptual change seen in drawings. The larger study examines four research questions. Three questions address quantitative measures of knowledge, attitude and observational skills. The fourth question compares the perception of the activity to the quantified measures. The smaller study examines a correlation between cognitive differences and drawing products.

Drawing and Biology Content Knowledge (RQ1)

Students in one Introductory Biology lecture (n=141) were randomly assigned to one of three treatment groups: Writing, Drawing, or Drawing with Instruction. All students took a biological knowledge pre-test during the first week of the semester, and then repeated the same test at the end of the semester. The three groups experienced the same lecture material presented by the same lecturer. The laboratory component of the course presented the same material to the students, although the six sections were taught by three different teaching assistants.

The null hypothesis states that there should be no difference between the three groups, either at the start of the study because the groups are randomly assorted or at the conclusion of the study because the differences between groups (type of workbook assignments) should
not affect overall general biology knowledge. Pilot study data, however, suggest that groups of students who draw in lab should perform slightly, but significantly, better on a subject-related exam.

Pre-/Post-testing (Knowledge)

The results of this study indicate that, of students who took both (pre- and post-) knowledge tests, there is no significant difference between the three groups at the beginning of this study (Figure 6). The post-tests indicate that all students gained biological knowledge over the course of the semester, as expected. There is a significant difference in post-test grades between the Drawing with Instruction group and the Writing group. The Drawing with Instruction group scored, on average, over six percentage points higher (Figure 6). There is no significant difference in post-test performance between the Drawing and Writing groups, or between the Drawing group and Drawing with Instruction group.
Interestingly, the post-test averages on this test were lower than the post-test performance on a similar test used in the pilot study (non-biology majors). This is unexpected and may indicate a problem with the validity of the test for use with these students.

While post-test performance indicates a statistical difference between the Writing group and Drawing with Instruction group only, improvement in test scores for each student indicates a slightly different conclusion. Student improvement in content knowledge show significant differences between the Writing group, which showed less improvement, and both Drawing groups (see Figure 7).
When examining the overall final grades in class (as reported by the instructor of the lecture course) of the three groups, there was no statistical difference between groups. The Writing group averaged 82%, the Drawing group averaged 83%, and the Draw with Instruction group averaged 84%. Correlation between final grades in the class and knowledge test scores was 0.49, indicating a moderate to strong association between the two assessment methods.

Within each of the six laboratories, there were slight differences in change of knowledge between two of the labs. However, post-test scores on the content knowledge test were not significantly different. Also, I was concerned about the impact of different Teaching Assistants on the content knowledge performance of the students. Confidence Intervals were analyzed among the three TAs, resulting in no significant differences among the Teaching Assistants.
Observations of Student Behavior:

Other researchers have suggested that drawing activities positively affect the number or intellectual-level of student-generated questions. I observed two laboratory sections each week with the intention of collecting empirical data to address this suggestion. However, the few number of questions asked during the drawing activity precludes a quantitative analysis between groups. Most student-generated questions were procedural in nature. Students asked the most questions during a laboratory involving microscopic pond organisms (e.g. "Do y'all have jellyfish looking things?" "Is it supposed to move?" "Is that considered plankton?")

During a laboratory on plant evolution, the Lab Workbook assignment requested that students draw/describe a plant with its evolutionary adaptations to land. Before the workbooks were submitted, the Teaching Assistant reviewed all the specimens in lab, verbally describing the land adaptations for each plant. No student re-opened his/her workbook to edit or add information. Frequently, the observer noticed that workbook assignments were completed by the students before the TA introduced the materials or instructed the students on the activity.

A few of the students made extremely detailed drawings of these plant specimens, taking up to 28 minutes on their assignments. When the TA reviewed the material and began introducing the next activity, those students continued to focus on their drawing activity, apparently ignoring the TA.

Students from all three groups exhibited a range of observational behaviors, from careful and serious observations to quick and cursory observations. These behaviors relate more to observational skills, so the data are discussed in that section. Also, the time spent on
Workbook activities varied greatly. This information is also described in the observational skills section.

Lab Workbooks:

Students in the Writing group and Drawing with Instruction group produced more detailed descriptions (verbal or visual) in their workbook assignments than students in the Drawing group. Examples of detailed and imprecise entries follow.

Figure 8. Examples of detailed visual descriptions (top row) and imprecise visual descriptions (bottom row).
Examples of detailed verbal descriptions
Student 1 (skull): “Overall teardrop shape (mouth comes to a point); Teeth: upper incisors absent; There is a diastema (gap) between incisors & molars; molars and premolars are in back; The front of the premaxilla (upper skull): opening with jagged edges (for nose); posterior to this opening is opening on both sides of skull (sinus?); the orbitals are just posterior to this opening; there are upper masseter points posterior to the orbitals which allow lower & upper jaw to be attached”

Student 2 (paramecium): “After the dark treatment, the paramecium looked relatively the same. However the differences were the clear outer layer seemed to take up more space in the specimen. They seem to be more of a round shape. Some look as though they were folded up. The specimen also seem to be dead they are not moving. They have a green tint to them also maybe brown. The color seems to be more uniform on some. But on others the clear parts seem to take over. The organelles are no longer distinct and are much harder to see. The specimen seems to have become more predominantly brown. You can still see the cilia hair on the outer layer.”

Examples of imprecise verbal descriptions
Student 1 (skull): “The carnivore skull had large front canines to rip through flesh/meat. It has molars all the way to the back of the jaw. It is a bigger skull meaning that it is more than likely a larger animal.”

Student 2 (plankton): “slender with spines on front and back”

From a grader’s perspective, misconceptions were easier to spot in the Writing group because those students were required to verbally describe the objects, forcing students to place more verbal labels on structures. However, since the students had not been taught about the anatomy of these objects, the students may not have had adequate vocabulary to describe the structures. For example, common misconceptions include the description of veins in a bee wing as “bones” and algae in lichens as “blood” (due to the staining process of the prepared slide). Members of the Drawing groups did not, in general, label those structures because it was not requested in the assignment. Therefore, the Drawing groups could draw their observations and address the specifics of the assignment with their labels. The Writing
group had to describe their observations first. Most did not have the vocabulary or anatomical understanding to be able to make accurate descriptions.

In drawings, labeled structures alerted the instructor to misconceptions. Two such examples include students who labeled the stipe in a mushroom cross-section as a “nucleus,” or declaring “no endosymbiotic algae found” in a paramecium while providing contradictory evidence (drawing the spherical algae inside the organism and labeling it “green”). In other words, the advantage of the drawings (when labeled) is that the grader could identify that the student actually did SEE the structures in question, but that students could not identify or comprehend their observations.

Drawings were also faster and easier to grade, as student hand-writing can be difficult to decipher. In addition, students seemed to understand the drawing assignment better, as those who wrote descriptions produced exceedingly vague, general observations more often.

Interviews:

Only three students agreed to be interviewed; two from the writing group ("William" and "Wanda") and one from the Drawing with Instruction group ("David"). During these interviews, I reviewed the survey responses of the students and asked them for specific examples or further explanation of the responses. The interview with "William" was very involved with his views as a former social science major, comparing the differences between biology and humanities. While his comments apply to other aspects of this research and will be described below, his interview did not specifically address the effects of his workbook assignments on his content knowledge.
Wanda described how she, at first, would have preferred to draw:

"The girl beside me was drawing and I was jealous cause I didn't know what to write." "I feel like maybe I would have like seen more of the detail [if I was drawing] instead of like searching frantically for it to write it all down." "They had to just draw what's there, so you can't really go wrong."

But over time, Wanda acclimated to the assignments and saw the benefits of writing:

"I started looking at things better so I could describe it better because at the beginning I didn't really talk about anything except its size." "This kinda helped... me learn what I was actually describing, like by writing the name and everything. Just like Paramecium bursara [sic] I would have probably forgotten that's what I drew but I wrote it." "With the microscope because it's so small and so like they all look like the same but if you have to describe what you're seeing, you have to look at it and see what's the difference in it and what you looked at before kind of - in order to write about it."

David described how his opinion of drawing changed over time and how the instruction he received at the beginning of the semester affected his drawings.

"At first I was kind of ... skeptical of the drawing idea but then once I realized that it you know had been helping. It was not really a big time sink, it only takes five minutes so um yea, I kinda grew to like it and benefit from it."

"The overall drawing in general made me notice little features that I wouldn't have even thought of otherwise. Like, if you were just to tell me to draw an animal skull, it wouldn't be anywhere near as detailed as that - or even the inside of a heart."

David further discussed how the drawings affected his learning and compared drawing activities to writing.

"Drawing helped me ... label and you know memorize what parts went where in that particular region of the plant."

"If I was writing and I had to write it in a lab um a book like this and I had to go on and do experiments, I may have just ... wrote something, just take notes and then moved on to the experiment. But with drawing, I was more interested in the drawing so I did it and I tried to do a good job. Um, but with writing it's basically just looking at something and writing an observation. It may not, for me it wouldn't stick as easy as labeling the parts of a heart, for example. Like I'd say the left ventricle and the right ventricle goes to this part, but if I had a drawing, I can see it rather than just write it down, which I remember that way."
David also addressed an issue which many students, in my experience, report when they see their cheek cells for the first time. They are generally surprised or confused that the organelles are not clearly visible, as images in textbooks show all the cellular structures so clearly.

"I didn't see as many organs [sic] as I thought I would within the Paramecium mainly because in previous classes I had looked at, you know, a detailed like animation picture so to speak where they were actually you know brought out to you so you could see them easy. So I was kind of surprised not to see some of those."

Drawing and Attitude Toward Biology (RQ2)

Pre-/Post-testing (Attitude)

The same students who participated in the pre- and post-knowledge tests also gave their opinions on the usefulness of, personal enjoyment of, and self-efficacy in biology. This assessment, adapted from the Attitude Toward Science Inventory, consisted of 24 questions measured by a Likert scale (see Appendix B).

Based on pilot study data, I hypothesized that students who draw should indicate a more positive attitude toward biology than those who write. This hypothesis is not supported by the data. There was no significant difference between the pre-tests or post-tests of any of the three groups (Figure 8). While the increase in positive attitude of the Drawing with Instruction group appears strong, it is not significantly different from the other two groups (Figure 9).
However, there is one very important difference between the Pilot Study and Study One: the students’ majors. Attitude toward biology among students in Study One (biology majors) is very positive, which greatly affected the possibility of change in attitude over time.
(the “ceiling” effect). If a student answers every question in the Inventory in the most positive manner, a total score of 120 points is possible. The pre-test averages for these students were in the 90s. The average score per question is 3.75, which means that students must rate individual questions in the highest category (5) for a substantial positive shift to be seen in the data. Among the non-majors group, the pre-test average score per question was 2.75, which allowed more room for 'movement' on either side for the post-questionnaire.

Survey:

Attitude toward Biology includes self-efficacy. One survey question addressed pride in the assignments a student produced. When asked if they were proud of any of the workbook assignment they produced, students replied with significantly different responses based on the treatment group (Figure 16). Students with writing assignments were the least proud of their work. The Drawing group indicated a significantly more positive response to the question, and the Drawing with Instruction group revealed the most positive response, two standard deviations from the Writing group.
There were no moderate or strong correlations between attitude and the students' lab section (or instructor), pride in assignments or enjoyment of drawing activities.

Experimental Design Issues:

Two major experimental design issues created problems in measuring Attitude toward Biology. The most significant issue is the use of biology majors, as described above. The second issue is the difficulty in measuring Attitude toward Biology, not Attitude toward the Laboratory Workbook assignments. Interviews did not address attitude toward biology specifically. While all three students interviewed had positive attitudes toward their workbook assignments, these students were not randomly selected. Observations were made of students during their workbook assignments. Behaviors which may have indicated pleasure or displeasure were probably related to the assignments, rather than a general attitude toward biology.
Drawing and Observational Skills (RQ3)

Pre-/Post-testing (Observational Skills)

The Observational Skills Assessment (OSA) was administered as a pre- and post-test. There were no significant differences between any of the groups in the pre-tests or post-tests (Figure 10). There was a slight decrease in average scores between the pre- and post-tests. While this decrease is not significant for any of the groups, it is an interesting trend. The trend could indicate an actual decrease in average Observational Skills, less interest in taking the post-test, or a test-process error.

I suspect the cause of the decrease is a test-process error. The OSA was timed (5 minutes). According to my observations while administering the test, many students were recording more detail in their post-test drawings, indicating an increase in Observational
Skills. However, because of the time limit, these students did not complete the test and, as a result, received a lower score.

The pre-/post-OSA results for this study are very different from the pilot study data. In the pilot study, students with drawing assignments showed significant improvement in OSA scores on post-tests, while students with writing assignments did not. The major differences between the pilot study and this study are that pilot study participants were non-science majors, were assigned groups by lab section rather than individually, had assignments which were both perceptual and conceptual, and were taught by the principle investigator.

The issue of the students' majors may affect the OSA scores. When comparing pre-OSA scores, there is a significant difference between the two study groups: biology majors and non-science majors (Figure 11). While further investigation is needed, the higher initial scores among biology majors may indicate more difficulty in raising the scores further. However, this supposition is not likely since the maximum score on the OSA is 31.

![Figure 13. Average OSA Scores for Science majors and Non-science majors](image)
The two experimental design changes (groups assigned individually and limiting assignments to perceptual data only) between the pilot study and this study may more accurately address the individual perceptual skills. However, there may be an important factor of drawing as a social activity and form of communication. Students who draw share their Workbooks with peers more often than students who write. Students drawing as a group may strive to increase their skills more than students drawing individually.

I also investigated the TA’s attitude toward the Lab Workbooks as a factor of student performance. Since I, as the principle investigator, have a positive opinion of drawing as a classroom assignment, it may have influenced the students in the pilot study. Of the three TAs in Study One, one TA had a favorable opinion of drawing as a classroom activity and one TA clearly held negative opinions of the workbook assignments. The students of the TA with a positive view indicated a decrease of 0.28 on the OSA while the students of the TA with a negative view dropped 0.38 on the OSA. These numbers show a very small, and not significant, difference between the two TAs.

The OSA does correlate moderately well in test-retest reliability for this study (r=0.66). Most students (78-89%) scored between three and four points (10% of the total points available) of their original score. When comparing the post-test performance to students' final lab grades, the correlation is 0.46. While there is no statistical difference between A-, B-, or C-students and their score on the OSA, there is a trend in the averages (Figure 12). In comparison, very low correlations exist between post-OSA scores and lab section (r=0.12) or gender (r=0.04).
Lab Workbooks:

When comparing the weekly drawings of the two Draw groups, the level of detail in visual descriptions indicate that the original instruction did help the Drawing with Instruction group (Figure 13). However, over time, the two groups' scores began to coincide. This may indicate that either the Drawing group improved over the semester, or the Drawing with Instruction group worsened.
Figure 15. Scores of Weekly Assignments over Time (Drawing and Drawing with Instruction groups)

Each drawing assignment was graded on a three-point scale (1 = conceptual drawing, cartoon-like, low accuracy; 2 = poor perceptual drawing, realistic but with few or inaccurate details; 3 = good perceptual drawing, realistic with accurate details). Examples of different quality of drawings are found in Figure 14.
Figure 16. Examples of Scoring of Student Lab Drawings

The drawing of a dissected crayfish (assignment 9) was expected to be the most difficult subject. It was included as a type of 'negative control'. The bee wings (assignment 3) were expected to be the easiest subject and were included as a type of 'positive control'.

The two higher-scoring laboratory drawings (Assignments 3 and 8) were the bee wing (the ‘positive control’ which students drew from a picture) and the skull with which students were probably most familiar. The two lowest performing laboratory drawings (Assignments 4 and 9) were plants and dissected crayfish (the ‘negative control’). The plants may have been very difficult for the students to draw, as prior assignments had been simple objects from two-dimensions. The plant lab (Assignment 4) was the first three-dimensional drawing assignment for the student. Assignment 7 was another plant drawing (a flower) and the students in the Drawing group did significantly better. One of the three students interviewed
addressed some potential explanations of the poorer performance on Assignment 4 by saying
"I don't personally like drawing plants. I think they're kind of dull to draw and it's repetitive... it's not something that's interesting to me to draw. If the directions had specified a certain, like, focus on, like, part of the plant instead of having us spend the time drawing the stems and, like, the leaves maybe if, like, it focused on, like, a leaf and pistol and stomata-type thing, like, if it just focused on a certain part of the plant that the teacher's trying to focus on in class." One more contributing factor to the students' poor descriptions/drawings of the plant assignment comes from my personal observations. I noted that students were standing during this lab and not spending a long time drawing. They were also choosing to draw the larger specimens on display, which were not necessarily in front of them. For instance, my notes describe a student sitting at a table with a display of mosses but drawing the pine bough at a different table. I also noted that many students were drawing the pine branch. I speculate that students may have considered pine needles easy to draw (conceptually as straight lines), which might have been a contributing factor to the low average score of this lab’s drawings.

Survey:

When asked "Did you notice any details on an object that you drew/described that you wouldn’t have noticed otherwise?", the Drawing with Instruction group averaged the most positive response, although none of the groups were significantly different (Table 2). These responses are interesting, as generally less than half of the students believe that the assignments caused them to examine specimens more closely. This opinion is contradictory to many other data collected in other studies and to other perceptions collected in this study
as well as in others. The question may have been poorly worded, or the students may have held a negative view overall of the assignments when completing this survey, or the students may not realize how much more closely they are observing objects when doing these assignments.

Table 2. Average Responses of the Three Treatment Group to Question about Observation of Details

<table>
<thead>
<tr>
<th>Group</th>
<th>Average Response (0=No; 1=Yes)</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Writing</td>
<td>0.429 ± 0.077</td>
<td></td>
</tr>
<tr>
<td>Drawing</td>
<td>0.413 ± 0.073</td>
<td></td>
</tr>
<tr>
<td>Drawing with Instruction</td>
<td>0.500 ± 0.080</td>
<td></td>
</tr>
</tbody>
</table>

Observations of Student Behaviors:

I observed a number of interesting student behaviors over the course of this study. The most frequent, and least expected, of these behaviors involved a student briefly glancing at a specimen, returning to his/her seat and then beginning the workbook assignment. This behavior was surprising because I had assumed that all students would be looking at an object while writing about it or drawing it. Of the 21 instances when I noted students making entries in their workbooks without looking at specimens, ten students were in the Writing group, five were in the Drawing group, and six were in the Drawing with Instruction group. Alternatively, I observed 27 instances of students exhibiting "looking behavior" (closely observing an object and glancing back-and-forth between the object and the workbook). Of these occurrences, seven students were in the Writing group, nine were in the Drawing group, and eleven were in the Drawing with Instruction group.
I also recorded the amount of time students spent on drawing. These data are useful in general terms only due to the collection methods, discussed below. In the first two labs, workbook activities averaged less than five minutes. Workbook activities in the remaining labs averaged six to ten minutes. When comparing groups, the Writing group and Drawing group averaged 6.3 (range 3 to 10) minutes and 7 (range 4 to 10) minutes respectively. Students in the Drawing with Instruction group averaged 14.3 (range 8 to 23) minutes on their assignments. Students may spend longer on the activity because they are adding more information or detail to their submission, or because they are less efficient at completing the activity. Since the latter explanation is not supported by any evidence, we may conclude that more time spent on the activity is related to the recording (and observing) of more information.

There are some important strengths and weaknesses of these data. The strength is that I, as the observer, did not know to which group each student was assigned. While the students' Lab Workbooks would have indicated that, those workbooks were not visible to the observer. Therefore, behaviors recorded in the observer's notebook were unbiased, but also limited, by that information. The weaknesses are that these times are skewed to the reporting of longer amounts of time. If a student finished the assignment in under a minute, the observer may have missed it while observing another student. Also, the large variation in time spent working on activities, between students and between assignments, increases the probability of error in these averages. Two of the laboratories required students to move throughout the room, making it difficult to track students during those labs. Finally, students often started
and stopped their assignments rather than working on them until completion, increasing error in collecting time data.

*Interviews:*

All three students interviewed addressed the benefits of closely observing specimens. Wanda (in the Writing group) focused on how the workbook assignments caused her to improve her observational skills over time:

"I started looking at things better so I could describe it better because at the beginning I didn't really talk about anything except its size [and color]."

However, as Wanda continued to explain what she looked at as the class progressed, she mentioned how organisms moved or what organisms were related. While these are important observations and knowledge for biologists, she did not address observing more details or correcting observations of shapes or structures. She also used an example of "relationships" between organisms as the Paramecium related to a Cladoceran and Bosmina. While it was impressive that this student remembered these scientific names of organisms, the relationship is inaccurate. While they are all small organisms living in pond water, Parameciums are protozoans (Kingdom Protista) while the Cladocerans, which include Bosmina, are crustaceans (Kingdom Animalia).

William felt that he was often rushed in completing the Workbook assignments:

"Because they were presented as a separate entity from the lab class... and time was usually limited because so much stuff was packed into the lab, it was usually 'oh, my green workbook. I completely forgot. So I'd better just get this over with'."

But as the semester progressed, William described how his observational skills improved and how this skill differed from the Humanities background he'd had:
"I think I got better at observing closely things, which, is obviously a very important part of science."

"As I learned more about biology, I learned more about what I needed to look for. I was able to look at, focus on those aspects that really contributed to that rather than just being lost and just writing down random things."

"I'm coming from a liberal arts background and so I think I had to learn how to think like a scientist. What is a scientist looking for and what are they trying to observe and once I got the hang of that after a few weeks, I think it improved."

"Liberal arts focuses on generalities and broad-sweeping statements and you use evidence to support but... science takes the evidence to a whole 'nother level... It's very detail oriented and... the importance is in the details and that's how everything is interconnected in science. And that's where you see the interconnections and why things are the way they are, so it starts at the microscopic level and then builds up to the macroscopic whereas the liberal arts, I think we're completely focused on this macroscopic level and we need evidence to support what we're saying but it's not, not so precise."

William also addressed the conceptual changes which took place as he used his improved observational skills and scientific thought process:

"As I'd learn science and biology and how to look through that lens,... I had preconceived notions and then, being able to look at these things first-hand. I mean, the preconceived notions are mostly stereotypes or generalizations and then when you see things at this very detailed level and when you start really looking at things at a detailed level, um, then those generalizations don't apply and they aren't always true. And so that, I mean, I remember several times doing this, thinking that's not at all what I would expect. Like the evolutionary relationships between things, dinosaurs and birds and uh just things like that, it just really surprised me. And then looking at hearts - all that stuff, it just really, it was really surprising to me."

David, from the Drawing with Instruction group, described how the drawing activities "put [the] images in your head" or "helped the objects imprint in your mind" when he completed his survey about the workbook activities. He reiterated this association of drawing with memory when interviewed:

"If I'm doing something with my hands, like even writing, drawing, it kind of sticks in my memory better."

"With writing it's basically just looking at something and writing an observation. It may not, for me it wouldn't stick as easy as labeling the parts of a heart, for example. Like I'd say
the left ventricle and the right ventricle goes to this part, but if I had a drawing, I can see it rather than just write it down, which I remember that way."

David addressed level of observational skills required to complete the activity:

"The overall drawing in general made me notice little features that I wouldn't have even thought of otherwise."

He responded with both the benefits and weaknesses of the comments or suggestions written about each drawing and ways to improve:

"It helped 'cause I knew what to look for next time."
"The comments... would have been hind-sight biased because you're going back and you're "ok, I understand now" or I could've I noticed something like that, I just didn't take it into consideration. But... since we didn't you know look at the same thing twice, um, it really, it was more of uh it was more difficult to correct the observation because we couldn't, uh we weren't drawing it again."

Student Perceptions of Drawing (RQ4)

As for the students' own perceptions of the effect of the workbook assignments on their knowledge of biology, all three groups were divided in their opinions. The Drawing with Instruction group, on average, had the most positive view when answering the question "Do you think the Workbook assignments increased your knowledge of the objects you observed?" The Drawing group had the most negative opinion, significantly less than the Drawing with Instruction group (Figure 15).
When surveyed about the workbook activities, students provided varied information. Students stated that, when given the choice between writing assignments and drawing assignments, they preferred drawing overwhelmingly (Table 3).

**Table 3. Percent of Student Preference for Type of Assignment (by Treatment Group)**

<table>
<thead>
<tr>
<th>Group</th>
<th>Percent prefer writing assignments</th>
<th>Percent prefer drawing assignments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Writing</td>
<td>17%</td>
<td>83%</td>
</tr>
<tr>
<td>Drawing</td>
<td>26%</td>
<td>74%</td>
</tr>
<tr>
<td>Drawing with Instruction</td>
<td>29%</td>
<td>71%</td>
</tr>
</tbody>
</table>

When asked to imagine a biology class that utilized drawing assignment, most students did not think the assignment would affect their enjoyment of the class. However, students in the Drawing and Drawing with Instruction groups responded more often with a negative view on drawing in class (see Table 4). When reflecting on the previous set of data, we see
the same pattern emerge: students who drew in this experiment were more likely to prefer writing assignments.

Table 4. Student Perceptions of Enjoyment of Class if Presented with Different Assignments (by Treatment Group)

<table>
<thead>
<tr>
<th>Group</th>
<th>Would enjoy class more with drawing</th>
<th>Would enjoy class less with drawing</th>
<th>No preference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Writing</td>
<td>30%</td>
<td>18%</td>
<td>53%</td>
</tr>
<tr>
<td>Drawing</td>
<td>20%</td>
<td>26%</td>
<td>54%</td>
</tr>
<tr>
<td>Drawing with Instruction</td>
<td>16%</td>
<td>30%</td>
<td>54%</td>
</tr>
</tbody>
</table>

If both tables are examined, the data are extremely consistent. In Table 3, the students who prefer writing assignments have similar percentages to the students who would enjoy class less if it included drawing assignments (Table 4). The students who would prefer drawing assignments (from Table 3) are the total of students who would enjoy class with more drawing and those with no preference (from Table 4). It appears that students who do not appear to have a preferred method of instruction overwhelmingly choose the drawing activities if given only the choice between the two assignments.

Observations of Student Behaviors:

Most students worked on their workbook assignments for short periods of time (4-6 minutes) without comment or behavior which reflected positively or negatively of the work. A few students appeared frustrated when first using their Lab Workbook (during the first paramecium lab) and during the fungus diversity laboratory. The fungus diversity laboratory was also the one with the most errors in the student workbook, and the most errors presented by TAs during the class (e.g. describing the stipe of a mushroom cross-section as the “nucleus”).
During the first laboratory observed (Paramecium activity), two students in the Writing group and one in the Drawing with Instruction group exhibited behaviors of frustration. These behaviors included heavy sighs accompanied by pushing the workbook away, vigorously erasing entire pages and rolling eyes, or commenting as one student said, "This is so stupid" (this student also exclaims later in the semester "school sucks" so the negative comment recorded here may not be in reference to the workbook activity, but a general comment on the course or an overall negative attitude). During the third lab (Bee wing activity), three students show their workbooks to their peers while smiling, as though exhibiting their work. This behavior may indicate a pride in their assignments. All three of these students had drawing assignments. One of the students in this lab exhibits a behavior which I described as a "head close" behavior; the head is down very close to the workbook and the student exhibits little distraction by the other activities or students in lab. This behavior is seen many times among the drawers. During the fungus diversity lab, four students from all three treatment groups exhibit frustration. One student in the Writing group complains "I picked the hardest one." Two students show their drawings to their peers. In the remaining labs, students who have shown their drawings to their peers continue to do so each week.

Conceptual Change and Individual Cognitive Processes (RQ5)

The purpose of Study Two was to further investigate the unexpected student behaviors observed in Study One. Students from all three treatment groups exhibited looking behaviors and non-looking behaviors. Looking behavior indicates that the student is taking in visual
data to build a perceptual drawing. Non-looking behavior can either indicate that a student has perfect recall of visual information, which is improbable, or that the student is working from preconceptions to build a conceptual drawing. There would be differences between these two types of drawings in level of accuracy and detail.

One should acknowledge that conceptual drawings often look "better" than perceptual drawings because they are what is expected to be seen, by both the student and the grader. For instance, in the drawings below (Figure 17), a student with Non-Looking Behavior produced a good conceptual representation of a heart. However, the atria are never equal in size, or larger than, the ventricles and, when dissecting a heart, one rarely makes a perfect coronal section of the organ. The student who exhibited Looking Behavior when drawing the heart made an accurate sketch of the object, recording observational data rather than preconceptions.
Figure 18. Examples of Drawings Produced by Students Exhibiting Looking and Non-Looking Behaviors

The idea of this study was to identify one group of students that continually made conceptual drawings and one group that made perceptual drawings. This would be accomplished through videos of the participants in their laboratory, comparing the looking behaviors among the students, and through the students' drawings.

Unfortunately, the videos, when combined with the laboratory set-up and movement of the students, were of insufficient quality to use for this purpose. The identification of students
as conceptual or perceptual drawers is limited to the drawings produced in their laboratory workbooks.

Student workbooks were grouped into one of five categories:

1 = drawings consistently very conceptual
2 = most drawings conceptual
3 = mix of conceptual and perceptual drawings
4 = most drawings perceptual
5 = drawings consistently very perceptual

Examples of Category 1 and Category 5 workbook entries are below (Figure 18).

Originally, I’d intended to group the students into two or three groups. However, as the students produced different drawings each week, these classifications seemed too limited.
While I did not have the use of the videos, I did utilize one comparison on looking behaviors. Two students needed to make-up a lab. As they completed their perceptual drawings, I recorded the time it took each student to finish their assignment and the number of glances each made at the specimen. One student, who ended up in Category 5, took 5 minutes to complete the drawing and glanced at the object 11 times. The other student, who was placed in Category 1, completed her drawing 1 minute and only looked at the object 2 times.
times. Clearly, no conclusions should be made from these limited data, but they are the only data I could collect without the videos.

Each student took a series of cognitive tests at the beginning of the semester. These tests addressed 'hemispheric dominance' (right/left, mental rotation, Meyer-Briggs for visual/verbal & sequential/global) and 'conservatism' (conservative issue, need for closure, self-reported political and religious identities). The duplication of tests fulfilled the purpose of checking the reliability and validity of the results. Unfortunately, the data collected from these measures often did not support each other.

**Hemispheric Dominance:**

A student who exhibits 'right hemispheric dominance' should demonstrate high scores for the right-hemispheric dominance test, mental rotation, visual and global processing. When examining correlations between these tests, only the hemispheric dominance test and mental rotation were moderately correlated (r=0.42). The remainder of the test correlations had r-values between -0.13 and 0.17. Therefore, only the hemispheric dominance and mental rotation tests were used to compare to student drawings. The correlation between student workbooks and hemispheric dominance was r=0; and with mental rotation was r=0.21.

**Conservatism:**

When comparing correlations between the various 'conservatism' tests, stronger relationships were seen than between the hemispheric dominance tests. It is expected that a student exhibiting high conservatism should demonstrate higher scores on Conservative
Issues, Need for Closure, self-reported belief in God and self-reported Conservative political views.

The Conservative Issues test was strongly correlated with self-reported political views (r=0.72). Self-reported belief in God was slightly correlated to the Conservative Issues and self-reported political views (r=0.33 and r=0.34). The Need for Closure Scale was not correlated with any of the other assessments (range r=0 to r=0.05). While other researchers have found stronger associations between Need for Closure and Conservatism, I did not find the same relationship (Webster & Kruglanski, 1994). However, I used the Need for Closure test because it was, in my opinion, a better cognitive test reflecting the function of the ACC, as well as a descriptor of the difference between conceptual and perceptual processes. Therefore, both Conservative Issues and Need for Closure were compared to student drawings.

The correlation between student workbooks (1=most conceptual and 5=most perceptual) and Conservative Issues was r=-0.29; and with Need for Closure was r=-0.27. While the small number of students in this study limits further analysis of these data, I have graphed the averages of the conceptual/perceptual groups to illustrate an interesting trend (Figures 19 and 20). On average, students who produced more conceptual drawings scored higher in conservatism and need for closure, while students who produced more perceptual drawings scored lower.
Figure 20. Average Scores on the Conservative Issues Scale among Different Levels of Cognitive Change (by Conceptual or Perceptual Level of Observational Drawings)

Figure 21. Average Scores on the Need for Closure Scale among Different Levels of Cognitive Change (by Conceptual or Perceptual Level of Observational Drawings)
Conclusion:

Educators have positive opinions about the use of drawing as a teaching and learning tool in the biology classroom. Other studies have lacked empirical evidence or used quasi-experimental design. Study One of this research examined drawing as a learning tool using pre- and post-tests and randomized assignments for individual students. The data indicate that students who use drawing do learn slightly more than their writing counterparts. Attitude and observational skills do not indicate any difference between the drawing and writing groups. Student perceptions of the activity are positive, but not as strongly as other researchers have suggested.

Study Two focused on a behavior which concerned an assumption I had made before this research began; that students, especially in the drawing groups, would need to look at an object when drawing it. Since many students did not exhibit looking-behavior, I designed another experiment to compare level of conceptual change to cognitive factors. Learning styles were not correlated with conceptual change, supporting the limitations of learning styles as an applicable teaching method. However, conservatism and need for closure did result in correlations with level of conceptual change demonstrated through student-generated drawings.

I must stress that Study Two had a small sample size and was intended to be an investigatory study only. The correlations seen in the results are not necessarily causes of conceptual change.
CHAPTER 5: DISCUSSION

Drawing is perceived by teachers and students as a way to maintain student focus and attention to detail. As such, drawing is assumed to be a positive influence on learning. However, few empirical studies test this claim. The best designed experiments investigating drawing and learning have dealt with conceptual drawing rather than perceptual or observational drawing, which is the subject of this research.

The two studies described here focus on perceptual drawing and its impact on student learning through observation and conceptual change. Observational skills, so important in biology, consist of student focus, attention to detail, and accuracy in perception of an object’s structure. If a student notices more detail and comprehends structures based on perception, rather than preconception, they may be more likely to observe physical evidence which conflicts with their current beliefs, thereby increasing the level of cognitive change.

Study One compared three treatment groups (Writing, Drawing, and Drawing with Instruction) for differences in student performance and attitudes in an introductory biology course. While 141 students participated in this semester-long study, only 87 completed all 17 assignments and assessments. This translated to approximately 30 students per treatment.

Most students complete this introductory biology course in the fall, but this study was conducted in the spring so that all students would have the same lecturer. However, the study participants may be a non-standard group. Some may have dropped or failed in the fall, or transferred from another school or major, as was the case with one of the interviewed students. Some students may not have been able to take the course in the fall due to a full
schedule or full classes. This non-standard group of biology majors may have impacted portions of this study. However, the main research question (#1), whether drawing activities have an impact on student learning, is a general assessment of the usefulness of this teaching tool. As such, the type of student who uses drawing should not be a factor.

Study Two was designed to investigate a behavior exhibited by students in Study One. Many students made no attempt at observing an object while describing it. This unexpected approach made me question if some students thought their preconceptions, or general observations, were detailed enough for scientific descriptions. Some students seemed to accept descriptions with substantial errors, while other students focused on accuracy in the details. I tested a group of students to see if ‘learning styles’ (a commonly cited difference among students) or a cognitive ‘need for closure’ would be different between students exhibiting different looking behaviors.

Drawing and Biology Content Knowledge (RQ1)

The main approach to assessing this question was a pre-/post-test covering general biology knowledge addressed in the course. The data support the hypothesis that students assigned drawing activities will demonstrate a slight, but statistically significant increase in knowledge when compared to students assigned writing activities. Since the hypothesis was derived from similar results of a Pilot Study, the conclusion has been upheld with two different methodological approaches. In the pilot study, drawing and writing activities were assigned to entire classes of students, whereas the students in Study One were randomly assigned activities individually.
When examining the results of the content knowledge assessment, the entire Study One group scored an average of 51% on the pre-test (substantially higher than the non-science majors, who scored an average of 45% on a similar test in the Pilot Study). The average post-test score was 68%, an increase of 17 percentage points. When looking at the average increase of knowledge as 17 percentage points, the fact that drawing groups scored 3-6% higher than writing groups appears much more substantial (18-35% difference in improvement in scores).

Visual perception tasks can be an important aspect of the scientific curriculum, as everyday observation is insufficient to adequately make scientific conclusions (Eberbach & Crowley, 2009). While both the writing and drawing activities used in this experiment required visual observation skills, the act of recording these observations through drawing seems to help students learn or remember more. Kozbelt (2001) examined performance of artists and non-artists on perception tasks and found that artists were significantly stronger in visual cognition and mental interaction with objects. Since biology often requires a keen use of observation in minute details or pattern recognition (e.g. anatomical differences between species), strong visual cognition can be a vital skill.

Another difference between the groups is that the writing group may have struggled due to unfamiliarity with scientific terms, or with the act of making detailed descriptions of objects. This type of activity (written, detailed descriptions of objects) may not be used frequently in the primary or secondary school curriculum. Many studies which address writing as a learning tool focus on conceptual assignments. Using drawing to describe an
object may be easier or less frustrating to complete without the vocabulary and anatomical knowledge of an expert.

Writing has been extensively researched as a learning tool and is seen as beneficial for mental processing and memory when compared to traditional, non-writing groups (Balgopal & Wallace, 2009; Hand, Hohenshell, & Prain, 2004; Nieswandt & Bellomo, 2009; Rivard & Straw, 2000). Since drawing outperformed writing in this study, it may show even stronger gains in learning if compared to a ‘control’ group without an additional activity.

Drawing Instruction:

There is a difference between students who drew after receiving instruction and those who drew with no prior instruction. The instruction module at the beginning of the semester did not exceed ten minutes and was followed by minimal comments on weekly student drawings. It should be noted that the differences between the Drawing and Drawing with Instruction groups were not well-controlled since the differences between the two groups include not only the drawing instruction, but the weekly comments supplied to the Drawing with Instruction group as well.

Instruction in observation has shown increased abilities in diagnostics for medical personnel (Bardes, Gillers, & Herman, 2001; Dolev, Friedlaender, & Braverman, 2001; Edwards, Reynon, & Etal, 2000; Kirklin, Duncan, McBride, Hunt, & Griffin, 2007; Naghshineh et al., 2008; Rodenhauser, Stricland, & Gambala, 2004; Shapiro, 2006). Also, artists with experience in drawing show greater activation of the right frontal lobe of the brain (Solso, 2001). This can indicate the use of higher cognitive functions.
Instruction in perceptual drawing is important, as many students will default to conceptual drawing. Conceptual drawing, as a record of student conceptions, is useful in understanding student thoughts but not in examining student perceptions. If one is attempting to challenge preconceptions, a perceptual drawing is a more useful tool. This should be of vital concern to the educational community. If observational drawing is to be utilized as a teaching tool, instruction and guidance are paramount.

**Issues with Measurement Tool:**

The test used for biological content knowledge would have been more accurate if it contained more questions. However, it was intentionally kept short (38 questions) due to time restrictions in the class. Further studies involving drawing as a learning tool should utilize more comprehensive content tests, or preferably a decrease in the amount of information covered between pre- and post-tests.

Students did not receive credit for taking this exam, which may have affected their performance on the test, especially on the post-test, as many students experience fatigue toward the end of the semester. Also, the post-test was delivered by a teaching assistant, rather than the normal instructor of the course. This difference in the rank of the test-administrator may have had a general effect on student motivation. However, any of these effects would have applied to all groups so the differences between groups are not affected.

**Comparison of Knowledge Test and Final Grades:**

The final grades in class were not significantly different between groups, although averages indicate a slightly higher average for the two drawing groups. The lecture course
itself consisted of 150 minutes of instruction per week for 16 weeks, with twelve labs of 160 minutes each. The ten workbook activities averaged five to ten minutes per week which equates to 1-2% of total class time. A study which utilizes more time on workbook activities may result in greater effects on final grades.

Observations of Student Behaviors indicating Content Knowledge:

The main goal of observing students was to record and compare quality of questions asked. Other studies (Hayes, Symington, & Martin, 1994; Matern & Feliciano, 2000) addressed the number or level of questions asked by students as a result of drawing activities. In this study, analysis of student-initiated questions was difficult as the observer could not hear many questions asked in the lab setting. Most students asked questions amongst themselves. If students did direct questions to the TA, it occurred while the TA was at their table. Students often asked questions in a low tone so that only the TA could hear. Since the students were often looking at different structures in this lab course, the TA would usually answer that student’s question individually, not directing it to the entire class.

While the collection and analysis of student questions could not be gathered, observations were made of other student behaviors. Students in drawing groups demonstrated more attention-behaviors and spent more time on-task than students who wrote. While this does not necessarily result in increased learning, attention is a primary step in the learning process.

However, the intensity of student focus may have negatively impacted learning. A few students were so intent on working on their drawings that they did not seem to notice when
the instructor made comments or moved on to another activity. While this observation supports the premise that drawing causes students to pay attention and focus on a specimen, this behavior can cause a student to miss vital information provided by the teacher. It would have been ideal if the instructors made sure to have all their students’ attention before summing up one activity or moving on to the next.

During the plant lab, when students did not revisit their workbooks as the instructor noted structures addressed in the assignment, student behavior could be explained by the following hypotheses:

- Students may not have been paying attention to the TA, as the review occurred at the end of the activity when many students are ready to move on to the next activity. According to student comments, this laboratory was viewed as unimportant and of low interest since it dealt with plants.

- Students may not care about the correction of their knowledge, or of their workbooks. Some students expressed negative comments about the lab manual assignment (a large chart of characteristics for different groups of plants) associated with this lab. Since many of the students seemed preoccupied with filling in the chart, and not with actually observing the specimens to figure out the answers, this assignment may have overwhelmed the students.

- Students may have forgotten about the lab workbooks (with their written or drawn descriptions). Students commented that the workbooks were an additional assignment, outside of regular lab work. Frequently, students and/or TAs forgot about the workbook assignments until the end of the activity. Often,
students completed the workbook assignment before the activity began. Since the TAs were not grading the workbooks, they rarely mentioned the assignment other than the “begin” or “end” announcements.

If students were completing the assignment to get it out of the way (before the instructional materials or activities are introduced) and the students do not go back to their entries to modify them, then the content of the workbooks are less effective than they could be. In other labs, besides the Plant lab, many students were observed to go back and edit their Lab Workbook activities independently, although I could not be sure what information or modification a student made since I only saw the final product.

Indications of Content Knowledge Gain within Activity Workbooks:

The Lab Workbooks from Study One are poor indicators of student knowledge gain as they were not designed to serve that purpose. However, they can be used as tools to determine student misconceptions. Both treatments (writing and drawing) were beneficial for identifying some student misconceptions. In general, the writing assignments made it easier to identify misconceptions since students were interpreting their visual perceptions. However, the drawings were useful in understanding what the student actually observed.

For practical purposes, assignments may be most beneficial if writing and drawing assignments are paired. Students in this study were not presented with anatomical information (for instance, the parts of a bee wing). If this information were presented, they may have been able to more accurately label their drawings or describe their wings.
The benefit of drawing is that it allows students to describe an object visually without having to know vocabulary. Teachers can use a drawing to ensure that the student is seeing structures correctly. Then, the teachers can address mental misconceptions, especially by using the student’s own drawing to incorporate ownership. Other researchers have also addressed this ability for instructors to become aware of and correct student misconceptions (Stein & Power, 1996).

Originally, I had not considered the descriptions from a grader’s perspective. I’d considered the drawings as a communication tool, between student and teacher, as a way for instructors to formatively assess student visual perceptions (especially during microscope activities, when the teacher may not be sure of what the student is observing). As a grader though, the drawings made it much easier to comprehend what the student observed when they completed the assignment. The laboratory, as a practical experience, makes use of many specimens from which students may choose or view at different angles (for instance, the plant lab offered a variety of plants from algae, moss, and ferns, to gymnosperms and angiosperms). It was difficult to determine which object the students in the Writing group were examining when they completed their assignment. As such, it was challenging, if not impossible, to make corrections.

Another negative aspect associated with writing assignments is handwriting. Many students had handwriting so illegible that no conclusions could be made from their work. While students could be asked to type their descriptions or focus on legibility, this comment is made only as an observation of difficulty with written assignments compared to the
drawings. If students made drawings that were indecipherable, the grade would be affected, since accuracy and detail are major components of perceptual drawing.

Summary:

Does drawing help students learn? The data from this study does indicate a correlation between the drawing activities and content knowledge. Further studies should examine specific aspects of drawing that may promote learning or memory. Drawing may require students to look at an object longer or more closely, or it may be a more enjoyable task which influences student motivation or persistence. These two aspects (attitude and observational skills) were examined in this study and are addressed below.

Study Two further investigated explanations for drawing’s effectiveness among students. Van Meter (2001) suggests that drawing forces students to self-monitor and detect errors in comprehension, although she used conceptual drawing. The looking behaviors of students observed in Study One led me to further investigate error-detection.

If drawing activities do help students learn, are they worth the time? This is the question asked by educational researchers in the 1920s and 1930s. They concluded that drawing was an inefficient educational approach due to the long amounts of class time spent drawing (Johnson 1933, Ballew 1930, Miller 1928). In this study, drawings made by the participants were small, simple sketches that took an average of 5-10 minutes, yet still helped improve the students’ attention to detail. Perhaps teachers in the early 20th century cared more about the appearance of the final product (as a summative assessment) than the reasons for making the product (as a formative assessment).
Drawing and Attitude Toward Biology (RQ2)

The data collected in Study One indicate that no statistical differences in attitude toward biology are found between the treatment groups. Attitude Toward Biology became more positive for all three groups throughout the semester, the average score increasing most for the students in the Drawing with Instruction group. This conclusion supports the data from the pilot study. However, while students indicate positive attitudes toward drawing, the activity does not appear to cross-over to student attitude toward the subject.

The experimental design for this research question was flawed. Study participants were biology majors, who indicated very positive attitudes toward biology on the pre-test. The results of the modified ATSI were markedly higher in this group of science majors when compared to the non-science majors tested in the pilot study. This is expected, but lessened the possibility of significant improvement in attitude over the course of the semester. Therefore, the choice of study participants made it unlikely to see any significant improvement in scores.

Another possible concern about the experimental design used to answer this question is the difficulty in triangulating data. The modified ATSI test was a good measurement of Attitude Toward Biology. However, other assessments including the survey, observations, and interviews, examined students’ opinions of the drawing or writing activities, rather than their opinion of biology. While these data do provide some insight into student attitudes, the data do not address the original research question.
Drawing Instruction:

While the instruction in drawing was rudimentary (a 5-10 minute lesson during the first laboratory session), it may have a strong influence over student perception of the activity. However, the influence may not be the drawing lesson itself, but the comments in the students’ workbooks. I did make a conscious effort to limit my comments to the three aspects of drawing covered in the drawing instruction (shape, detail and texture). Comments on drawings are often viewed by the students as critical (personal experience). To avoid this negativity, I skewed the comments to the positive (for example: “Good job on textures, work more on details next time”). This positive feedback on student drawings may have influenced student opinion of the activity. However, that is not to say that drawing instruction at the start of the semester does not influence how students perceive the workbooks as a learning tool. Since most students state that the assignments helped them focus and pay more attention to detail, this may have been perceived as an increase in knowledge.

Observations of Student Attitude Toward Biology:

Attitude Toward Biology is difficult to assess by observation, especially when the observer cannot hear student comments. I focused on two types of student behaviors, which may indicate level of enjoyment in the laboratory experience.

The first behavior is positive interaction with peers. These behaviors include smiling at peers (while working on lab-related assignments) and sharing work with peers. The drawing groups outnumber writing groups in these behaviors while completing their Workbook assignments.
The second behavior involves time spent on Lab Workbook assignments. Many students hurriedly finished their work, as though extrinsically motivated to merely complete the assignment. Other students spend more time (and exert more focus) on assignments, as though intrinsically motivated to create a product of which s/he is proud. Students with drawing activities also more often fell into the latter category than the students with writing activities.

I only recorded observations during the Workbook activity portion of each laboratory. As a result, these observations are limited. However, students were working on regular laboratory activities during this time frame as well.

Summary:

All three groups showed a more positive Attitude Toward Biology over the course of the semester. The greatest average change, on average, occurred in the Drawing With Instruction group although none of the changes were significantly different from each other, or significantly different between pre- and post-tests.

Further study should address this question with non-science majors. The pilot study indicated that non-science majors who draw develop a significantly more positive attitude toward the subject. Non-science majors generally dislike biology or feel that they are “no good” in the subject (French & Russell, 2006; Lawson, Banks, & Logvin, 2006; Tranter, 2004). If the drawing activity can improve these students’ attitudes toward biology, it may increase persistence or sense of accomplishment.
Students lose interest in science due to difficulty level, a lack of hands-on activities, poor teaching and irrelevance (Delpech, 2002; Osborne, Simon, & Collins, 2003; Prokop, Prokop, & Tunnicliffe, 2007). If drawing activities are effectively used, they may be seen as hands-on activities that are easy for students and allow them to use their own observations to make conclusions. This encourages students to take responsibility for their own learning, and increases the relevance of making real-life observations.

In general, student attitude was mildly correlated ($r=0.31$) with their grades in the class. Since students assigned drawing activities indicate improvement in content knowledge, this may explain the slight increase in attitude. Accomplishment in class, rather than the drawing activities, may be more likely to result in improved attitude.

Overall, the impact of drawing on student Attitudes Toward Biology is difficult to assess. Attitude is hard to separate from achievement or grades in class. Self-reported assessments are tricky tools as students may have difficulty deciphering attitudes toward the subject and enjoyment of the class overall (attitude toward activities, instructors, and/or teaching techniques).

Drawing and Observational Skills (RQ3)

The data indicate no differences in Observational Skills among any of the three groups, or from pre- to post-test. There was even a slight decrease in average scores on the OSA over the semester.

Of course, one explanation for these results is that the students did not improve (or even declined in) their ability to make accurate, detailed observations. Many participants in this
study made quick, careless observations and, according to survey responses, just wanted to complete their Workbooks to get back to the regular lab activities. These students may have ‘practiced’ this careless behavior all semester, which resulted in lower scores on the OSA.

Another hypothesis to explain the decrease in scores is that the students did not have sufficient time to complete the OSA task. I developed this hypothesis while observing participants during the administration of the post-OSA. To investigate, I conducted a small study in which twelve people were offered a free three-hour drawing lesson. The participants took the OSA at the beginning of the lesson and at the end. Those participants who were novice drawers showed a 10% improvement in their OSA scores. However, the participants who had more drawing experience showed a decline in their scores because they did not finish in the time allotted. Further study should address this phenomenon, as this small investigation is insufficient.

Another hypothesis is that students are disgruntled about taking many extra tests, which do not affect their grades. This may be seen as “busy-work” by students, especially by the end of the semester, and they may experience frustration with the assessment. At the end of the semester, students are much more stressed, hurried, and focused on grades than at the beginning of the semester. The OSA was intentionally developed to avoid any requirement for biological knowledge, which may make the assessment look unimportant to students.

Lastly, the lack in improvement in scores may be explained by the lack of instruction on observation. There is a strong correlation between amount of drawing instruction and scores on the OSA. The students in this study had, at most, ten minutes of instruction with limited comments to address observational errors. Most students had no instruction or
comments. While I had hypothesized, based on the pilot study, that the students would show improvement, it is not surprising that they did not. I was the instructor of the labs of the pilot study, and answered student questions about the level of detail or accuracy of their drawings as they completed their assignments. Also, I had incorporated the drawings into the lab as an activity that the class worked on at one time. I suspect this encouraged the students to use more time making their observations due to peer interactions or a lack of benefit to finishing the task early. While I did not record the amount of time students spent on their drawings during the pilot study, I would estimate 15-20 minutes per lab. In Study One, students who completed their task early could get back to the ‘real work’ of the lab. There was a distinct benefit to students hurrying through their Workbook assignments.

*Compare OSA with Final Grades:*

There are interesting correlations between final grades and student scores on the post-OSA. The Writing group had a correlation value of 0.01 between grades and OSA scores, while the Drawing and Drawing With Instruction groups showed correlations of 0.31 and 0.17 respectively. These correlations are minimal, but they do raise further questions about observational skills and classroom performance. Does practicing Observation (attention to detail, accuracy, and focus) by drawing lead to higher grades?

*Observations of Student Behaviors indicating Observational Skills:*

Two major behaviors were noted while observing students as they completed their Workbook activities. The first involved task persistence or focus. The Drawing with Instruction group spent a longer amount of time on their assignments than the Drawing or
Writing groups. This could indicate that Drawing with Instruction students were paying much closer attention to and spending more time with the objects. However, since most students finished the activity in less than 10 minutes, the instructor moved on to other laboratory activities. Those students spending more than 10 minutes were doing so at the expense of listening to their instructor, which could negatively impact learning.

The second behavior I observed was unexpected. I had assumed that students would visually or verbally describe an object while looking at it. This assumption was quickly and clearly refuted by my observations. Many students looked only briefly at an object before completing their assignment. Other students made frequent eye movements from the object to their workbooks. These looking behaviors have been described by researchers in the fields of both cognition and the arts (Fish & Scrivener, 1990; Miall & Tchalenko, 2001). Artists make these eye movements more consistently and efficiently than non-artists. The artist locks his gaze on a single detail, while novices may look at multiple, unrelated structures.

These behaviors may best be described by the theoretical concept of working memory (Atkinson & Shiffrin, 1971; Baddeley, 2003). If a student can only hold a small amount of information in short-term memory, s/he will need to look frequently at an object when observing details closely. The limit to the amount of information held in memory at one time would support consistent looking behaviors.

Students who do not exhibit looking behaviors would be recording pre-conceptual information in their workbooks, rather than actual perceptions. The differences between descriptions made by students with and without looking behaviors would therefore be visible in their Workbook products, especially for the two Drawing groups. Students with looking
behaviors should have more detail in their drawings. Students with non-looking behaviors may produce drawings that look aesthetically better to a grader (because they are the visual expectation of an object) but are less accurate records of perceptions. The structures may be clearer in conceptual drawings because the students are drawing what they think the structures should look like, or what they’ve seen in the past in biology texts or graphics.

Looking behaviors seem to differ by group. The data are composed of a small number of observations so no definitive conclusions can be made. However, the observations indicate that students in the writing group had the fewest looking behaviors while students in the Drawing with Instruction group had the most.

The looking behaviors used by students in Study One led to the development of Research Question Five, addressed in Study Two. I was curious about the use of preconceptions in drawings, which should be perceptual. Why did some students accept inaccuracies in their Workbook assignments? Did they think their preconceptions were sufficient? Did they not recognize the number of errors in their drawings? Do they have a resistance to changing their preconceptions?

Indications of Observational Skills within Activity Workbooks:

The average quality of workbook drawings by the Drawing with Instruction group was consistent, but the Drawing group’s quality improved half way through the semester. Of course, the scores on these drawing are imprecise as they are general and are assessing images of different objects. A more structured measurement tool would be useful, although difficult to develop.
The quality of workbook submissions was wide-ranging between students. Some students drew precisely detailed, accurate representations while others scribbled cartoon versions of objects. Even the writing submissions showed a range from detailed description to random lists of generalized traits. This could be explained by two factors: the difference in student perception of detail, or the difference in student description of detail. It would be beneficial if one is to utilize drawing (or writing) as a teaching tool, to give students examples of the type of work expected of them. This could address the difference in student description of detail.

Students made better observations of objects that were in two-dimensions, as well as those objects which were most interesting to them. Two-dimensional objects are easier to draw because the mind does not have to overcome misperceptions of three-dimensionality. Level of interest may be an undervalued aspect in observation. If students are interested, they look longer and more closely, observing more precise details and challenging pre-conceptions.

Training and Practice in Observational Skills:

The amount of drawing utilized in this study (on average 5-10 minutes per week; 50-100 minutes total for the semester) is negligible for improvement of observational skills. To see if drawing activities increase observational skills, it may be more appropriate to examine a class that utilizes more time drawing.

There is a very strong correlation between the OSA and the amount of experience a student has drawing. While one may address the obvious assumption that the OSA is a test
which utilizes drawing, I suggest that the OSA uses a very specific type of drawing. The test does not require a student to “Draw a jar with lollipops” and then grade the drawing on the level of detail, which would be a conceptual test. The OSA requires students to record what they see. Anyone who can write can manipulate a pencil. This task merely asks the participant to manipulate a pencil to create a mimic of the object in front of them. Students with experience drawing have been trained in observational skills to overcome their misperceptions. ‘Learning to draw’ is a misnomer, as the act would be better described as ‘learning to see.’

Student Comments related to Observational Skills:

The most common student-generated response (from 64 students) on the survey addressed how the Workbook assignments caused students to look more closely at objects or pay more attention. Roughly half of the students from each of the three groups recorded this self-generated response. When comparing this response to a question on the survey addressing a similar concept, students in the Drawing with Instruction group had comparable numbers; 50% of the respondents within the group responded positively. However, only 41-43% of the other groups responded positively to the question about assignments causing them to look closely.

One hypothesis to explain this discrepancy of the data is that the survey was set up in the following manner:

9. Did you notice any details on an object that you drew/described that you wouldn’t have noticed otherwise? _____ Yes _____ No
   If yes, give an example. _____________________________________________________
The “Yes” selection has blanks on both sides, while the “No” selection just has one blank. If a student does not pay careful attention, s/he may accidentally select the wrong blank. The remainder of the survey was in this format, which would bring much of the data into question. Also, a “Yes” selection requires the student to fill in additional information, requiring more effort.

When further investigating the survey data, all groups had members generate these conflicting responses; six students in the Drawing with Instruction group, six students in the Writing group and nine students from the Drawing group. It is also important to remember that many students exhibited a non-looking behavior (looking once at a specimen and returning to their seat to complete the Workbook assignment). These students may be the ones who responded “No” to the survey question. A future study should compare student comments about their behavior to the actual looking behaviors exhibited.

Summary:

The results of this study are inconclusive in regards to Observational Skills. The assessment tool should be adjusted to allow the test-taker more time. Ideally, the participant should have as much time as s/he requires, since the test examines the accuracy of perception, not speed of perception.

There are inconsistent results in Observational Skills improvement between the pilot study and Study One. This may involve the social context of the assignments in the pilot study, the difference in skills of study participants, the direction received from the instructor, or a yet-overlooked factor.
Assignments were determined by lab group in the pilot study, thus the students had much more social interaction when completing their work. As in this study, the students participating in the pilot study showed their drawings to each other, possibly inspiring competition to produce better drawings.

Cognitive differences between the two groups of students may also play a role. As one of the interviewed students described, the sciences require a different level of detailed observation than the humanities. This might explain the differences in OSA averages between the two groups.

One other difference between the two groups should be investigated in the future. The biology majors were in a ‘high-stakes’ course for their major, whereas the non-science majors were taking an elective designed to be informative and fun. Many of the science major students worked to complete activities or assignments and then move on. As the Workbooks were likely viewed as extraneous assignments, the goal of many students may have been to ‘check off’ the task, rather than to pay attention and observe closely.

Observational skills are important for attention to detail and ability to interpret raw visual data. Tools can be developed so that the skill may be taught in schools, especially in secondary schools when focus on fine detail increases in significance. While science teachers and curriculum developers in secondary schools are probably aware of the importance of observational skills, it is not a concept specifically addressed at this level.

Drawing is not a challenging physical skill. Most students have the motor skills required to hold a pencil and make intentional marks on paper. The ability to perceive objects closely, carefully, and precisely is necessary not only in science but in every field of study.
Perhaps even more important is the ability to recognize and correct misperceptions. These skills are teachable and should be addressed in the curriculum.

Student Perceptions of Drawing Activities (RQ4)

A majority of students (70%) stated that they saw connections between drawing and biology. The most common student-generated response further describes observational skills as the main connection. Many students though, saw the activities as pointless or busywork. These attitudes were addressed in 15 comments from the Drawing with Instruction groups, but were found more often in the Drawing and Writing groups (25 comments and 20 comments respectively).

When asked if the Workbook assignment helped increase biological knowledge, the Drawing with Instruction group responded most positively (58% of respondents). This was significantly different from the Drawing group, which responded least positively (41% of respondents). Therefore, instruction and guidance in observation-based drawing assignments may be a key factor in student understanding of the value of the activity.

Most student comments about perceptions of the activities dealt with the enjoyment of the assignments, rather than how much the assignments contributed to biological understanding. These comments were generally positive and included pride in assignments, which may indicate intrinsic motivation, and enjoyment of the activities, which may affect persistence in task completion.

In Study One, 76% of the students preferred a drawing task when asked to choose between drawing or writing. However, over half of all students appeared to have no
preference, when given that option. This was an interesting set of data because it showed that 16-20% enjoyed their assigned activity, while 26-30% disliked their assigned activity regardless of group. The remainder indicated no preference, but chose drawing when forced to decide between writing or drawing. This may indicate that, while drawing is often perceived positively as an enjoyable activity, the strength of this opinion may be insubstantial.

Other studies in perceptions of drawing address student enjoyment of the activity and the positive view of drawing as a learning tool. Bland (2004) found that 89% of respondents saw drawing as a useful tool in biology class. He noted more positive responses among females and general education majors.

This study indicated no differences between male and female perception of Workbook assignments. The only difference was that females created more self-generated responses on the survey than males (120 unique comments from females and 88 unique comments from males).

Pride in Assignments:

The survey question dealing with student pride relates to intrinsic motivation, competence and perceived achievement (Nieswandt, 2007; Patall, Cooper, & Wynn, 2010; Vansteenkiste & Lens, 2006). Students who feel proud of products made in class will have a more positive opinion of the class, topic or activity. Drawing activities were much more likely to elicit such pride. And, perhaps surprisingly, the short instruction at the start of the semester with short weekly comments had a significant impact on student pride.
The data collected from this question may be the result of final products, as a drawing made by students would generally be seen as “a product” more than a written paragraph or list of characteristics. This is supported by comments made by the interviewed student “David” who stated that he tried harder to produce a good drawing, and that if he’d been writing, he probably would not have been so careful with his work. This ‘caring’ about the quality of work is an important aspect for intrinsic motivation, as well as pride in the finished product.

Another reason for the difference may be due to the commonly held belief of “I can’t draw.” The drawing products may have surprised students in realizing that they are more capable of drawing than previously thought.

Pride in assignments would be an interesting focus of further research. Those investigating drawing from a Vygotskian perspective would be most interested in student-student interactions and student-instructor communication. Writing assignments may still allow communication between students and the instructor, but students were not seen sharing writing assignments with their peers in this study.

Observations on Student Behaviors Indicating Perceptions:

Student behaviors during Workbook activities can indicate positive or negative perceptions of the tasks. Positive behaviors include smiling while sharing Workbook products with peers and focusing intently on the product (with a “head-down” behavior). Negative behaviors include small violent actions such as throwing or hitting the Workbook or writing utensil, heavy sighs, rolling eyes, or other avoidance behaviors.
While there were many examples of these behaviors, only a few students could be matched to their assigned groups (since many of the labs required students to move from their seats and I had only a seating chart to identify students, allowing me to match up names with assigned groups). More negative behaviors were observed at the beginning of the semester and were often repeated by the same students from week to week. Positive behaviors were also exhibited by a few students repeatedly. The positive behaviors that could be linked to student groups (n=3) were observed in students with Drawing assignments.

Summary:

While student opinions of drawing as a learning activity are positive, they may not be strong for most students. This does not mean that drawing is not an effective tool. Rather, instructors using the tool need to consider carefully the way it's used. If drawings (or written descriptions) can address misconceptions or misperceptions during the activity, the student will then have the evidence and time to tackle the issues. However, if students do not receive instructor comments until after the activity has passed, as one interviewed student discussed, it is too late to adjust conceptions about that topic. Although the skills are addressed in grading and/or commenting on drawings at a later time, instructors should make clear what students are expected to be learning (concepts, skills, or both).

Conceptual Change and Individual Cognitive Processes (RQ5)

This question evolved as I observed the participants in Study One. Some students made perceptual drawings in their Workbook activities, while some were clearly creating
conceptual entries. It was apparent that some students thought their conceptions were sufficiently accurate, whereas other students did not.

Participants in Study Two were all given the same assignments (pre-conceptual drawings at the start of lab, then drawings during lab which were to be perceptual). The students were given cognitive tests at the start of the semester. These were later compared with the amount of change seen between the student’s two drawings per lab.

Because this portion of the research was conducted on a small group (n=48), statistical analysis is hampered. However, trends in the data can be observed. Two sets of cognitive tests (learning styles or hemispheric dominance, and conservatism or need for closure) were compared to cognitive change observed in student drawings.

Pre-conceptual drawings were used as a baseline for student conceptions about biological specimens. The second drawing, made during lab, was intended to contradict preconceptions, allowing students to independently modify or change their conceptions. Most students had similar pre-conceptual drawing errors, but only some students corrected those errors when making their perceptual drawings. The other students maintained their pre-conceptions.

While most students fell into an average ‘conceptual change’ category, a few students made striking changes and a few made very slight changes. While data from all students were analyzed, the two extreme groups were the most interesting.

Learning styles (visual/verbal) and hemispheric dominance are contentious topics in educational literature. While many teachers promote the concepts, educational and cognitive researchers have not found empirical evidence to support their use in teaching (Pashler,
McDaniel, Rohrer, & Bjork, 2009). In this study, several tests of learning styles and hemispheric dominance were given to the students. Data suggest little reliability between tests. Two tests which did seem to support each other were the Hemispheric Dominance test and Mental Rotation test. Neither of these tests correlated with conceptual change seen in pre- and post-lab drawings.

Conservatism and Need for Closure have been addressed in research related to error detection. These two traits do indicate a trend when compared to student conceptual change. The students who exhibited large shifts in their conceptions scored lower on the conservatism and need for closure tests, while students who maintained their conceptions scored higher in conservatism and need for closure.

**Learning Styles/Hemispheric Dominance - Issues with Measurement Tools:**

Hemispheric dominance refers to neurological research that shows a lateralization in brain function. The left hemisphere of the cerebrum is influential in sequential or linear reasoning, language and logic. The right hemisphere prevails in global or holistic processing, visual functions such as mental rotation and facial recognition, and creativity. There are disputes regarding the level of localization of these functions. Some researchers have indicated that the localization is limited to the first few moments of neurological processing. Others stress plasticity and bilateral control over many of these functions. Most current neurological studies warn against the concept that some people use one cerebral hemisphere more than the other.
The tools used to assess hemispheric dominance showed little to no reliability. Therefore only two tests, hemispheric dominance (Hopper, 2003) and mental rotation (Shepard & Metzler, 1971), were used when examining the level of cognitive change exhibited by students.

*Learning Styles/Hemispheric Dominance – Observational Skills & Cognitive Change:*

The results of hemispheric dominance were inconclusive. The limited correlations between hemispheric dominance and conceptual change during observational drawing activities may be explained by the difficulties in locating reliable measurement tools. However, it could also be explained by the type of drawing utilized in this study. While drawing is generally seen as a right-hemispheric activity, the perceptual drawings made by the students require an organized, step-by-step (or sequential) approach, which is generally considered a left-hemispheric process. The objects, in general, are not drawn as a whole, but as a series of detailed pieces. This approach to drawing is the basis for its usefulness in overcoming Gesalt errors of perception.

One reason for investigating learning styles in Study Two was due to student-generated survey responses from Study One. Five percent of students mentioned their ‘learning styles’ or visual/verbal dominance. I later learned that a compulsory freshman course required students determine their learning style by taking the ILS assessment (Soloman & Felder, 2009). The assessment, also used in this study, did not indicate any reliably when compared with other similar tests. Also, the test strongly skewed students to the ‘visual’ or ‘right hemispheric’ dominance.
Conservatism/Need for Closure - Issues with Measurement Tools:

Many of the conservatism tests were strongly correlated (e.g. conservatism and religion), but I chose to use the Conservatism Issues test since I wanted to avoid the conflicts which may result from comparing a person’s religious devotion to learning. Jegede and Okebukola (1991) did address this correlation in their study of observational skills. However, the study included objects which were associated with negative spiritual beliefs. The objects that students observed in Study Two were not, to the best of my knowledge, linked to any religious narratives.

The Need for Closure assessment did not correlate well with other measurement tools. However, this cognitive trait is sufficiently different from the other aspects tested. Since Need for Closure is more descriptive and explanatory than the other traits, I chose to include it in this investigation. In future studies, multiple assessment tools should be assigned to test for reliability.

Conservatism/Need for Closure – Observational Skills & Cognitive Change:

Conservatism was initially considered as a remote factor to be used for comparison with learning in this study. Other research links religion and political attitudes to learning and information processing (Amodio et al., 2007; Carter, Hall, Carney, & Rosip, 2006; Dollinger, 2007; Jost, 2006; Tetlock, 1983). Recent studies have investigated correlations between conservative attitudes and genes, response to stimuli, physiological processes, and brain function and structure (Inzlicht et al., 2009; Oxley et al., 2008; Rothbart & Posner, 2005).
Study Two examined conservatism as it relates to conceptual change. The data collected from the study indicate that there is an inverse relationship between conservative attitudes and conceptual change. These data must be confirmed in additional studies which should be better controlled and more precisely designed.

One assumes, if vision is functional, that one can see. But while some students perceive and accept new information, while others ignore the new visual data. Current research in attention and inattention blindness have educational and cognitive researchers further investigating factors that cause people to disregard visual cues (Mack & Rock, 1999; Simons & Chabris, 1999; Strayer, Drews, & Johnston, 2003). If students are not trained in perceptual observation, they may experience more misperceptions, which may lead them to think that they can’t trust their visual perception.

Need for closure also correlated with conceptual change. This variable is interesting for many of the above reasons. However, it is also interesting in regards to neurological function. Need for closure is considered a result of pain or pleasure signals in the brain. The anterior cingulate cortex (ACC) is one area where these signals may be measured. While there are genetics associated with brain development, studies in neuroplasticity have shown the ability for the brain structure to change based on experiences (Blake, Heiser, Caywood, & Merzenich, 2006; Davidson & Lutz, 2007; Doidge, 2007). This study investigated factors in 18-year olds during their first year at college. Students may experience very different conflicts at this time. Age and situation of the participant should be taken into account in future studies, as these factors may change one’s need for closure over time.
Summary:

Data collected from Study Two suggest a connection between conservatism/need for closure and conceptual change. However, I do not feel that conservatism is an appropriate measure. Rather, another factor, such as Need for Closure or Executive Functions like cognitive persistence or flexibility, may affect both conservatism and conceptual change. Future research should address cognitive persistence and cognitive flexibility. Current research in the cognitive psychology and neuroscience focuses on the executive function of flexibility. Cognitive flexibility theory is based on the idea that individuals, when exposed to a pattern of stimuli, will develop neural pathways to process similar patterns in the future. Some people may keep multiple neural pathways (allowing for multiple approaches) or be capable of modifying pathways, whereas others may have more restricted pathways.

One final comment regarding the similarities between the student-produced pre-conceptual drawings: for many objects, this similarity could be attributed to the use of icons as language (e.g. the word “sun” is represented by a circle with lines radiating from it). For the skull lab, students made pre-conceptual drawings which appeared influenced by pirate flags, Halloween decorations or poison labels. During the cell lab, interestingly, many students were influenced by graphics seen in biology textbooks. Some students replicated the images with surprisingly detailed accuracy. Since this graphic was not presented to the students during the concurrent lecture course, this preconception must have been derived from 9th or 10th grade biology, or earlier. Many students made dispirited comments that most of the cell’s organelles were not visible in the compound microscope. Developers of lessons or textbooks may want to include actual photographs or perceptual images of structures with
conceptual graphics. Instructors may also ask students to address the similarities and differences between the conceptual and perceptual images to direct attention to the conflict.

Theoretical Framework - Modifications

Posner’s Theory of Conceptual Change was slightly modified to include the cognitive and observational skills addressed in this study. Since Posner’s theory requires plausible new evidence to contradict preconceptions, the ability to correctly perceive that new evidence and have a cognitive capability to modify conceptions would be necessary in order for conceptual change to occur. Data collected in this study, however, seem to indicate that cognitive skills influence perception, rather than perception leading to challenges in cognition (Figure 21). Therefore, cognitive skills have been moved ahead of observational skills in the theoretical process of conceptual change.
These data may be explained by executive function. Executive functions are defined as cognitive processes which regulate the ability to organize and manage tasks, selectively focus, self-monitor, overcome habitual behaviors and utilize working memory (Meltzer, 2007; Rothbart & Posner, 2005).

According to current research, executive function originates in the prefrontal cortex (PFC) of the cerebrum. There is emerging research to suggest connectivity between the PFC and sensory regions of the brain (Barcelo, Escera, Corral, & Perianez, 2006; Garcia-Garcia, Barcelo, Clemente, & Escera, 2010; Heekeren, Marrett, Bandettini, & Ungerleider, 2004;
Kayser, Buchsbaum, Erickson, & D'Esposito, 2010). The PFC controls attention and focus, recognizes novel patterns and is used in decision-making processes. All of these factors are within the scope of observational skills.

Looking behaviors described in this study may be indicative of attention and working memory. Both processes are considered aspects of executive function. Working memory (Baddeley, 2003) is important in creating perceptual drawings. Those students with higher gaze frequencies produce more accurate drawings than students with lower gaze frequencies (Cohen, 2005).

Future Research

Three aspects of this study would benefit from future research: the increase in content knowledge related to drawing activities, the measurement and development of observational skills, and further investigation of the link between executive function, observational skills and conceptual change.

Testing the increase in content knowledge through drawing should be examined in smaller, more acutely controlled studies. This study was large in scope and applied in a classroom setting. As a result, there were many uncontrolled variables, especially in relation to social interactions between students and TAs. Also, future studies should limit students to a smaller number of drawings and control the specimens available; preferably so all students are drawing the same object so that comparisons can be made more accurately.
Observational skills require better assessments and standardized educational approaches. This factor is large in scale since assessments, teaching modules, and standardization are all in need of development.

Research involving executive function and other neurological tasks are currently expanding. Attention, neuroplasticity, non-invasive diagnostic tools, and even genetic testing are currently the focus of cognitive research. As knowledge in these areas increases, better conclusions can be made from research in education and perceptual drawing.

Overall, all future research should address problems of experimental design. Due to the length of the study and lack of control over lessons, labs or timing for activities, there are many variables which may have affected the results of Study One. The most effective change would involve limiting the lessons and specimens. In both studies, students had ten lessons and could draw different specimens. This made comparisons between labs and between students very difficult.

Application of drawing as a learning tool

In the 1920s and 1930s, drawing was dismissed as a learning tool due to the amount of time spent on the drawings, and the difficulties in grading (many teachers graded on aesthetics rather than content). Rather than keeping the activity and modifying it to emphasize the positive qualities while reducing the negative ones, the activity was removed entirely.

In order to reduce the negative aspects of drawing in the classroom, students should be taught how to perceptually sketch. This activity can be completed in 10-20 minutes and is
sufficient to force students to observe objects closely and record visual data. It can also be used to check for student misconceptions. Students should be asked to focus on and label or describe certain structures which pertains to the lecture material. When communicating with students about their drawings, instructors should realize that students are very sensitive about their drawing abilities and a conscious effort must be made to encourage them. The drawings should be used as formative assessments only. If grades are to be assigned, they should rely on the accuracy and detail of the drawing, rather than the attractiveness of the final product. Along these same lines, some students may create beautiful drawings but with little important details or structures. This ought to be addressed by the instructor.

Drawings can also train students to discriminate between essential and non-essential information. A student may spend a large amount of time detailing one structure while completely ignoring the structure addressed in a lecture. A teacher can use this visual information to help students learn to focus on relevant information.

Most students can make careful sketches and label important structures. As for a students’ inability to draw, research suggests that it is not drawing (making marks on the paper) that is challenging to most people. Rather, it is the ability to accurately perceive. A student’s inability to draw may actually be poor perceptual skills, which should be addressed in the science classroom.

Johnston (2009) concluded that young children do observe closely. So why did so many students in this study disregard so much visual data? More research is needed to answer this question, but perhaps the response centers on preconceptions. Older students may have enough experience with objects to ‘label’ them by their names. If observational skills are not
subject to increasing refinement over the course of a student’s educational career, then students may believe they are adequately prepared to make conclusions from general, or quick visual input. Upon an initial overview of an object (which does not disrupt preconceptions), students place a ‘label’ on the object and move on. They no longer observe closely enough to challenge their preconceptions.

Training in higher-level observational skills is important in the science classroom. The ability to recognize the level of detail expected, and to recognize and correct errors is an essential process skill. Many students misperceive experiences due to inattention to detail or errors. Teachers can help students by setting a higher standard for detailed descriptions, giving examples, allowing students to practice, and gently correcting their work.

Conclusion

This study indicates that students who create a perceptual drawing for even a short time (five to ten minutes once a week) perform better on biology knowledge assessments. The students enjoy the activity and feel that it forces them to focus more and pay more attention to objects and structures.

These drawings are perceptual, rather than conceptual. While both types of drawings can indicate student conceptions about an object (even perceptual drawings can be influenced by the drawer’s preconceptions), the major difference between the two types is in the student’s ability to accurately perceive structures. This ability can be associated with observation of detail, focus, and ability to overcome Gestalt errors.
Some students look at an object once and then complete their assignments, clearly misperceiving the details of the object and relying more on their preconception. Since there is no conflict with this type of drawing, there is no conceptual change. Students who exhibit looking behaviors, repeatedly gazing at the object, may perceive it accurately or inaccurately. Training in observational skills may give students the tools to more accurately perceive.

The second study of this research project touched on the issue of “predisposition” to or “aptitude” in drawing. Researchers from the 1920s and 1930s complained that some students are more “gifted” in drawing and that the activity benefits them while disadvantaging others. Many people comment on an artist’s “talent”, “gift”, or “genes”, as though the ability to create a drawing is innate. I suggest that we underestimate the teaching of observational skills. Students must learn to closely observe, focus on details, and overcome individual misconceptions. The close observation required for perceptual drawings is aligned with the development of skills in attention, persistence and flexibility. Further research is needed to investigate executive function in relation to these skills.

This research project was conducted in a laboratory classroom setting over an entire semester. While this scenario is more applicable to practical applications, there were many uncontrolled variables in this design. While the instructor of the course was extremely amenable to the research, there were restrictions on both time and subjects taught. Future research should address more precise aspects of these studies, limit the scope of the project and control variables.
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Lindquist, N. (2008). FBI agent helps medical students with their observational skills. *UNMC Today*


Schell, R. E., McCroskery, J. H., Gooding, C. T., Swift, J. N., & Swift, P. R. (1987). Differences in students' perceptions for their high school biology and chemistry classes over the course of a school year. Paper presented at the Annual meeting of the eastern psychological association, Washington, DC.


APPENDIX A. Biology Content Knowledge test

25. Which of the following is a characteristic of all life?
   a. ingestion of food
   b. response to the environment
   c. use of oxygen
   d. sexual reproduction
   e. all of the above

26. The scientific name of a bobcat is *Felis rufus*. Which of the following organisms is most closely related to the bobcat?
   a. *Felis domesticus* (domestic cat)
   b. *Panthera leo* (lion)
   c. *Puma concolor* (cougar)
   d. *Leopardus pardalis* (ocelot)

27. The Kingdom Protista is thought to have given rise to which other kingdom(s)?
   a. animal
   b. fungi
   c. plant
   d. all of the above
   e. none of the above

28. Ducklings tend to follow any large moving object they encounter shortly after hatching. This behavior is called ____________.
   a. imprinting
   b. conditioning
   c. habituation
   d. altruism

29. The skull at the right is an example of a(n):
   a. herbivore
   b. carnivore
   c. omnivore
   d. detrivore
   e. insectivore

30. Which of the following biomes has the lowest carrying capacity?
   a. deciduous forest
   b. tropical rain forest
   c. savanna
   d. desert
31. The phrase “mad as a hatter” came about because people who made hats were exposed to mercury. The mercury built up in their bodies and affected their brains. Many toxins can build up in our bodies through exposure in our food, air, water, etc. Which concept refers to this absorption of toxins over time?
   a. Bioremediation
   b. Overexploitation
   c. Eutrophication
   d. Bioaccumulation

32. At which of the following trophic levels is the greatest amount of free energy available?
   a. Plants
   b. Mouse, Aphid, Ladybug
   c. Bird, Snake
   d. Fox
   e. All levels have the same amount of free energy available

33. Given the graph to the right, what conclusion would be most accurate about the relationship between the two species?
   a. The two species are competing for the same resources.
   b. The two species have a predator/prey relationship.
   c. The two species have a mutually symbiotic relationship.
   d. The two species have no relationship.

34. Two populations of frogs have been isolated from each other for a long period of time. According to the biological species concept, which of the following would demonstrate that the two populations have become separate species?
   a. the two populations differ in at least 4 morphological traits
   b. the two populations behave differently when exposed to the same dose of a chemical.
   c. When members of the two populations are mated, they produce sterile offspring
   d. DNA nucleotide sequences are different between the two populations

35. Which organelle stores the cell’s genetic information?
   a. golgi body
   b. endoplasmic reticulum
   c. mitochondrion
   d. nucleus
   e. ribosome
36. When DNA is extracted from cells of E. coli and analyzed for base composition, it is found that 40% of the bases are cytosine. What percentage of the bases is adenine?
   a. 10%
   b. 20%
   c. 40%
   d. 60%

37. Which of the following statements about RNA is true?
   a. it is double-stranded
   b. it contains uracil instead of thymine
   c. it is made of amino acids
   d. it is found only in the nucleus

38. Which of the following shows a pure dominant genotype?
   a. tt
   b. Tt
   c. TT
   d. None of the above

39. A blue butterfly mates with a yellow butterfly. Their offspring are all blue with yellow spots. This example shows what condition in genetics?
   a. incomplete dominance
   b. codominance
   c. complete dominance
   d. recessive trait

40. When you cross two red flowers, the offspring are red or white. What are the genotypes of the two parents?
   a. RR x RR
   b. Rr x RR
   c. Rr x Rr
   d. Rr x rr
   e. rr x rr

41. What is the main function of the fungal structure at right?
   a. photosynthesis (absorbs sunlight)
   b. transpiration (exchanges gasses)
   c. reproduction (releases spores)
   d. coevolution (attracts pollinators)

42. Which of the following statements about Darwinian evolution is FALSE?
   a. organisms tend to be perfectly adapted to their environments
   b. factors in the environment help determine which characteristics are preserved in a population
   c. if there is no variation in the population, evolution cannot occur
   d. evolution occurs at the population level, not individual
43. The unit of life in which biological evolution actually occurs is the
   a. individual
   b. population
   c. community
   d. ecosystem

44. According to the geologic sample at the right, which organisms appeared first in the fossil record?
   a. insects
   b. dinosaurs
   c. plants
   d. bacteria
   e. fish

45. A human’s arm and bat’s wing have the same bones, muscles and evolutionary origins, but very different present-day functions. What are these structures called?
   a. homologous structures
   b. vestigial organs
   c. analogous structures
   d. somatic structures

46. Which of the following are products of photosynthesis?
   a. carbon dioxide and water
   b. carbon dioxide and glucose
   c. glucose and oxygen
   d. oxygen and calcium

47. What part of the flower is illustrated in the figure to the right?
   a. ovary
   b. anther
   c. stigma
   d. sepal

48. Which of the following structures distributes water to all the cells of a plant?
   a. xylem
   b. phloem
   c. mycorrhizae
   d. stomata

49. Modern man (Homo sapiens) evolved approximately ______________ years ago.
   a. 3 million
   b. 1 million
   c. 200,000
   d. 6,000
50. What is the name of the anatomical structure marked in the illustration at the right?
   a. trachea
   b. spinal column
   c. intestine
   d. esophagus

51. Which of the following statements about enzymes is **NOT** true?
   a. Enzymes act as catalysts.
   b. Almost all enzymes are proteins.
   c. Enzymes operate most efficiently at optimum pH.
   d. Enzymes are destroyed during chemical reactions.

52. The exchange of oxygen into the blood and carbon dioxide into the lungs occurs in the ________.
   a. trachea
   b. heart
   c. bronchioles
   d. alveoli

53. Which type of blood vessels brings blood to the heart and is illustrated at the right?
   a. arteries
   b. veins
   c. capillaries
   d. lymph tubes

54. Which cells are produced in the bone marrow?
   a. B-cells
   b. red blood cells
   c. platelets
   d. all of the above
   e. none of the above

55. The left ventricle of the heart pumps blood to the ________.
   a. left atrium of the heart
   b. body
   c. lungs
   d. right ventricle
56. Which hormone is produced in the human testes?
   a. estrogen
   b. progesterone
   c. testosterone
   d. adrenaline

57. The lymphatic system is associated with:
   a. immunity
   b. digestion
   c. movement
   d. senses

58. If an animal’s brain stem was damaged, what would most likely happen to the animal?
   a. It would be unable to balance
   b. It would die
   c. It would become aggressive
   d. It would be unable to coordinate the movement of its right & left sides

59. Lichens are the result of which type of relationship between fungi and green algae?
   a. Commensalism
   b. Competition
   c. Parasitism
   d. Mutualism
   e. Predation

60. Which of the following affects the thickness of the ozone layer?
   a. CFCs
   b. Methane
   c. Carbon dioxide
   d. Radiation
   e. None of the Above

61. A man has 100 cells that undergo meiosis to form sperm cells. How many sperm cells will he have?
   a. 100
   b. 200
   c. 300
   d. 400

62. How many nitrogenous bases are needed to code for one amino acid?
   a. 1
   b. 2
   c. 3
   d. 4

63. Last year, Britain passed a law that will allow scientists to use hybrid animal-human embryos for stem-cell research. The researchers will inject the nucleus from a human skin cell into an empty rabbit egg cell. If the embryo could (or would be allowed to) grow into an adult organism, it would look like…
   a. A human
   b. A rabbit
   c. A mix between a human and rabbit
APPENDIX B. Modified Attitude Toward Science Inventory

For questions 1-24, please select from the following responses:

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<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Strongly agree</td>
<td>Agree</td>
<td>Neither agree nor</td>
<td>Disagree</td>
<td>Strongly disagree</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>disagree</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. ___ Biology is useful for solving the problems of everyday life.
2. ___ Biology is something that I enjoy very much.
3. ___ I do not do very well in biology.
4. ___ Doing biology labs or hands-on activities is fun
5. ___ There is little need for biology in most of today’s jobs.
6. ___ Biology is easy for me.
7. ___ Most people should study some biology
8. ___ I would like to spend less time in school studying biology
9. ___ Biology is helpful in understanding today’s world
10. ___ I usually understand what we are talking about in biology.
11. ___ I do not like anything about biology.
12. ___ No matter how hard I try, I cannot understand biology.
13. ___ I often think “I cannot do this” when a biology assignment seems hard.
14. ___ Biology is of great importance to a country’s development.
15. ___ It is important to know biology in order to get a good job
16. ___ I would like a job that does not use any biology.
17. ___ I enjoy talking to other people about biology
18. ___ I enjoy watching a biology program on television
19. ___ I am good at working biology labs and hands-on activities.
20. ___ You can get along perfectly well in everyday life without biology.
21. ___ I remember most of the things I learn in biology class.
22. ___ Most of the ideas in biology are not very useful.
23. ____ Biology is one of my favorite subjects.
24. ____ If I don’t see how to do a biology assignment, I never get it.
APPENDIX C. Student Survey

Lab Workbook Survey  
Participant Code ___ ___ ___ ___ ___ ___

1. Do you think the Green Lab Workbook assignments increased your knowledge of the objects you observed.  
_____ Yes _____ No  
Why or why not? __________________________________________________________

2. Did you recall any of the workbook assignments during a test or quiz?  
_____ Yes _____ No  
If yes, give an example. ______________________________________________________

3. Review your workbook. Are there any assignments you are proud of?  
_____ Yes _____ No  
If yes, give an example ______________________________________________________

4. How much time do you feel you had to work on the assignments in the workbook?  
_____ Too much time _____ Not enough time _____ The right amount of time

5. Do you feel that the assignments took too much time away from other lab activities?  
_____ Yes _____ No

6. Do you, or would you, like to draw in science class?  
_____ Yes _____ No  
Why or why not? _____________________________________________________________

7. If you spent time drawing in every biology class, do you think the drawing activity would change your enjoyment of the class?  
_____ I would enjoy it more _____ I would enjoy it less _____ No difference

8. Students either made drawings or wrote descriptions for their activities in their lab workbooks. Which group would you have preferred to be in?  
_____ Drawing group _____ Writing group  
Why would you choose this group? _____________________________________________

9. Did you notice any details on an object that you drew/described that you wouldn’t have noticed otherwise?  
_____ Yes _____ No  
If yes, give an example. ______________________________________________________

10. Do you see any connections between biology and drawing?  
_____ Yes _____ No  
If yes, describe the connections. ______________________________________________

11. Has your attitude toward drawing changed over the semester?  
_____ Yes _____ No  
If yes, explain. ______________________________________________________________
APPENDIX D. Survey Coding

**POSITIVE RESPONSE**
PA- Attention to detail; more detailed look; closer look; pay close attention; focus
PB- Memory; imprint in brain; recall information
PC- Reinforce lesson; reiterate words & concepts
PD- Understand better; learn better; think more; increase knowledge
PE- Visualize; image in head; picture in mind
PF- Connections; put things together; reflect
PG- Social; discuss entry with others
PH- Creative
PI- Interesting
PJ- Labeling; learn structures
PK- Enjoy; fun; better than writing; entertaining; like to draw
PL- Easy; easier than writing
PM- Conclusions from observations; investigate
PN- Use as reference
PO- Communication of observations; more descriptive
PP- Make reference; create own visuals; record data
PQ- Different activity; out of the norm; break from regular activities; hands-on
PR- Form describes function
PS- No stress; relaxing
PT- Slow down; spend more time

**NEGATIVE RESPONSE**
NN- Distracted from other activities/learning
NO- Replaced by technology; not necessary in present; photos better
NP- poor results; poor drawing
NQ- Writing is more descriptive; better than drawing (re: accuracy)
NR- No benefit; don’t see point of activity; not relative; no learning
NS- Tedious; boring; too easy
NT- Busy work; already made observations for other lab activity; duplicate; waste of time
NU- No enjoyment; No fun; don't like drawing (re: preference)
NV- Nuisance; annoying
NW- Stressed; negative emotion; frustration
NX- Difficult activity
NY- Observed generalities only; no specifics/detail; just listing facts; no processing
NZ- Forced to do assignment; For points/grade

**WITHIN RESPONSE**
R1- Used scientific terminology in response
R2- Refer to scientist
R3- Refer to Scientific Method
R4- Wrong example; scientific mistake
R5- Drawing used historically
SKILLS
S1- I don’t have to draw perfectly; no penalty for poor drawing
S2- Got better at drawing; not as bad as I thought
S3- Reference to drawing instruction (shape, shading, detail)
S4- Learning style; learning tool; visual/verbal/kinesthetic

SELF-EFFICACY
E1- I’m bad at drawing; low self-efficacy
E2- I’m a good drawer
E3- external efficacy; positive feedback from instructor

MISC.
C1- compare/contrast; pre-/post-conception; similarities/differences
X1- comment on grading, extraneous details
APPENDIX E. Hemispheric Dominance Inventory

Participant Code ____ ____ ____ ____ ____ ____

1. If you had to give someone directions to your house, which of the following methods would you most likely use?
   A. Write a paragraph that explains where and when to turn
   B. Draw a road map

2. Which of the following are you better at solving?
   A. Jigsaw puzzle  B. Crossword puzzle

3. Do you remember faces easily?  A. Yes  B. No

4. Do you think you'd earn higher grades in a geometry class or in an algebra class?
   A. geometry  B. algebra

5. Imagine that you're vacationing at a resort. Which of the following would you most likely do?
   A. Obtain a brochure of local attractions and plan what you'd like to do for the day
   B. Drive around without a plan and decide what you'd like to do as you drive along

6. Was it usually easy or difficult to learn grammar in school?  A. difficult  B. easy

7. Imagine enrolling in a music course. You and a partner in the course must write a song. Which of the following would you prefer to do?
   A. Write the lyrics  B. Compose the melody

8. When you read a new chapter in a textbook, which of the following are you most likely to do?
   A. Skim through the entire chapter first to get a general idea of what the chapter is about
   B. Read the chapter from beginning to end without doing much skimming

9. In which of the following English classes would you most likely enroll?
   A. Journalism  B. Creative writing

10. Imagine that you volunteered to work for the school newspaper. Which of the following would you rather do?
    A. Cut and paste and lay out the stories and decide which stories should appear where
    B. Write one or two of the stories

11. After reading a new chapter in a textbook, which of the following would you rather do?
    A. summarize the chapter  B. outline the chapter

12. If you had an important project due in a class, would you prefer to work?
    A. in a group  B. alone
13. ____ Which of the following classroom situations do you prefer?
   A. A teacher announces assignments on a weekly basis and sets specific weekly due dates
   B. A teacher announces all the assignments at the beginning of the course and allows you to complete them at any time before the end of the course

14. ____ Which of the following statements best applies to you?
   A. I'm good at guessing a person's mood by his or her body language
   B. I'm not good at guessing a person's mood by his or her body language

15. ____ Which of the following would you rather play? A. Scrabble B. Checkers

16. ____ When you walk into a theater, classroom, or auditorium (and assuming that there are no other influential factors), which side do you prefer?
   A. right    B. left

17. ____ When taking a test, which style of questions do you prefer?
   A. objective (true/false, multiple choice, matching)
   B. subjective (discussion, essay)

18. ____ Can you tell approximately how much time passed without a watch?
   A. yes    B. no

19. ____ When speaking, do you use few gestures, or do you use many gestures (that is, do you use your hands when you talk)?
   A. few gestures (very seldom use hands when you talk)
   B. many gestures (often use hands when you talk)

20. ____ Your desk or where you work is
   A. neat and organized    B. cluttered with stuff that you might need.

21. ____ When faced with a major change in life, you are
   A. excited    B. terrified

22. ____ Your preferred work style is like this:
   A. You concentrate on one task at a time until it is complete.
   B. You usually juggle several things at once.

23. ____ When reading a magazine, do you
   A. Jump in wherever looks most interesting
   B. Start at page one and read in sequential order

24. ____ If you were hanging a picture on a wall, would you
   A. Carefully measure to be sure it is centered and straight
   B. Put it where it looks right and move it if necessary
APPENDIX F. Need for Closure Scale

Participant Code ____  ____  ____  ____  ____  ____

In questions 1-42, you will select from the following responses:

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<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
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<td>Strongly agree</td>
<td>Agree</td>
<td>Neither agree nor disagree</td>
<td>Disagree</td>
<td>Strongly disagree</td>
</tr>
</tbody>
</table>

1. ____ I think that having clear rules and order at work is essential for success.
2. ____ Even after I've made up my mind about something, I am always eager to consider a different opinion.
3. ____ I don't like situations that are uncertain.
4. ____ I dislike questions which could be answered in many different ways.
5. ____ I like to have friends who are unpredictable.
6. ____ I find that a well ordered life with regular hours suits my temperament.
7. ____ When dining out, I like to go to places where I have been before so that I know what to expect.
8. ____ I feel uncomfortable when I don't understand the reason why an event occurred in my life.
9. ____ I feel irritated when one person disagrees with what everyone else in a group believes.
10. ____ I hate to change my plans at the last minute.
11. ____ I don't like to go into a situation without knowing what I can expect from it.
12. ____ When I go shopping, I have difficulty deciding exactly what it is that I want.
13. ____ When faced with a problem I usually see the one best solution very quickly.
14. ____ When I am confused about an important issue, I feel very upset.
15. ____ I tend to put off making important decisions until the last possible moment.
16. ____ I usually make important decisions quickly and confidently.
17. ____ I would describe myself as indecisive.
18. ____ I think it is fun to change my plans at the last moment.
19. ____ I enjoy the uncertainty of going into a new situation without knowing what might happen.
20. ____ My personal space is usually messy and disorganized.
21. ____ In most social conflicts, I can easily see which side is right and which is wrong.
22. ____ I tend to struggle with most decisions.
23. ____ I believe that orderliness and organization are among the most important characteristics of a good student.
24. ____ When considering most conflict situations, I can usually see how both sides could be right.
25. ____ I don't like to be with people who are capable of unexpected actions.
26. ____ I prefer to socialize with familiar friends because I know what to expect from them.
27. ____ I think that I would learn best in a class that lacks clearly stated objectives and requirements.
28. ____ When thinking about a problem, I consider as many different opinions on the issue as possible.
29. ____ I like to know what people are thinking all the time.
30. ____ I dislike it when a person's statement could mean many different things.
31. ____ It's annoying to listen to someone who cannot seem to make up his or her mind.
32. ____ I find that establishing a consistent routine enables me to enjoy life more.
33. ____ I enjoy having a clear and structured mode of life.
34. ____ I prefer interacting with people whose opinions are very different from my own.
35. ____ I like to have a place for everything and everything in its place.
36. ____ I feel uncomfortable when someone's meaning or intention is unclear to me.
37. ____ When trying to solve a problem I often see so many possible options that it's confusing.
38. ____ I always see many possible solutions to problems I face.
39. ____ I'd rather know bad news than stay in a state of uncertainty.
40. I do not usually consult many different opinions before forming my own view.

41. I dislike unpredictable situations.

42. I dislike the routine aspects of my work (studies).
APPENDIX G. Wilson-Patterson Issue Battery

Circle the opinion that most closely matches your own for each of the following social issues:

<table>
<thead>
<tr>
<th>Issue</th>
<th>For</th>
<th>Unsure</th>
<th>Against</th>
</tr>
</thead>
<tbody>
<tr>
<td>Death Penalty</td>
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<tr>
<td>Astrology</td>
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APPENDIX H. Religious Conviction and Political Conservativism

1. ____ Rank your belief in God:
   a. Certain God exists
   b. Uncertain God exists
   c. Certain God does not exist

2. ____ Rank your political views:
   a. extremely liberal
   b. somewhat liberal
   c. moderate or undecided
   d. somewhat conservative
   e. extremely conservative