

WHAT DID I LEARN?  
HELPING STUDENTS LEARN THROUGH SCIENTIFIC INQUIRY

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## ABSTRACT

Students enjoy doing labs in biology. However, too often the labs are prearranged cookbook labs where students follow detailed directions blindly without understanding lab concepts or purposes. This research was designed to increase student understanding of biological concepts through the use of frequent inquiry activities. In an effort to help students remember the importance and application of the lab, three self-reflection questions were included at the end of each activity: “What did I do? What did I see? What did I learn?” Pretests and post-tests were used to measure performance as well as formative assessments, surveys, and interviews. While quiz scores did not improve as a result of the treatment, student attitude towards science and labs became more positive.

## INTRODUCTION AND BACKGROUND

### Project Background

#### Teaching and Classroom Environment

Each high school student at Nyssa High (NHS) will take biology from me. As many teachers do, I hope my students will leave my class with a sense of excitement about science and learning. NHS is a school in a poor area, evidenced by 100% of the students receiving free meals for breakfast and lunch. Since my niche is biology teaching, I believe I can enhance the biology lab experience to benefit the students' lives.

Deprived or not, students often express excitement for biology labs. They give students a break from normal school work such as note-taking or bookwork. Lab participation also gives students an opportunity to learn kinesthetically. Even so, I have noticed that students still struggle with labs. They quickly forget the relevance and application of the activity once it is over. Furthermore, many students struggle with handling autonomy in the laboratory. They either lose focus or ask for teacher assistance with each detail of the lab assignment.

Much to my frustration, many students act as though the lab experience requires no thought at all, much like a knee jerk reflex: tap on the knee and the leg kicks, an action that uses the nervous system but bypasses the brain. Unfortunately, labs can be written for students to just follow the steps of the lab and get results without having to think. It gives me hope to believe that "all labs can be designed to offer students the opportunity to think instead of just do, to arrive at answers by integrating background information

with observations and results, rather than have answers dropped in their laps (Dickey, 1995, p. xiii).

I hope to give students lab experiences that would not only reinforce biological concepts learned in the regular classroom, but also explore new concepts. I would like to see improved student retention of lab concepts. Autonomy, confidence, and independent decision making in the lab setting would be an improvement indeed. To accomplish these goals, I decided to focus my action research on inquiry-based learning.

With inquiry-based activities as my research focus, I helped my students acknowledge the scientific purpose of labs. Specifically, students recognized the relevance and application to lecture material. My students acquired skills built by inquiry that will help them beyond the science classroom.

In the past, labs known as cookbook labs have been the norm in my classroom. Procedures were rigidly outlined, data tables were provided, and no real reflection questions were asked. Instead, simple and basic analysis about the lab and the procedure was given, much like following a recipe out of a cookbook. Thus, a low expectation of required personal investment was implied, which may have been a major contributing factor to my students' lack of understanding concepts upon lab completion. Increasing frequency of guided inquiry activities and an inclusion of reflective questions would be a way for me to help my students learn how science is carried out. Moreover, students would develop the skills needed to conduct an investigation or experiment in their own lives.

The purpose of my research was to increase the quality and frequency of inquiry-based labs in my classroom and determine its impacts on student learning. I looked at

attitude changes, both of students and myself, as more inquiry-based labs and activities were done. Incorporated with the increase of inquiry labs, I also included a short reflection section, “What did I do with my hands, what did I see or observe with my eyes, and what did I learn?” to see if reflection helped students retain lab concepts better.

### Focus Question

The main question and sub-questions I asked and researched are:

*How can learning through inquiry-based lessons enhance student understanding of biological concepts?*

- *To what extent can the inclusion of reflection strategies like “What did I do? What did I see? What did I learn?” increase student understanding of lab concepts?*
- *How does increased use of inquiry activities affect student attitude toward science and scientific inquiry labs?*
- *How does increased use of guided inquiry in the laboratory impact the teacher?*

Throughout my research, several people mentored me through the process. Ken Dickey is a chemistry teacher at NHS and served as a soundboard for many of my new ideas. He was the inspiration of this project as he recently incorporated self-reflection into his own labs. Luke Cleaver, the biology teacher at NHS before I was hired, is the vice principal of Nyssa High School. He had a treasure chest of ideas for labs and classroom management pointers. Hannah Schott, BSN, helped with the editing of my paper.

## CONCEPTUAL FRAMEWORK

In education, inquiry falls under the major theme of constructivism. While this theme has recently become popular, the more traditional take on education is a behaviorist point of view as explained shortly. Each major theory has its own positive points to them, but in the science classroom, inquiry has been found to be successful in helping students learn (Llewellyn, 2002).

What is inquiry? Inquiry is the “scientific process of active exploration by which we use critical, logical, and creative thinking skills to raise and engage in questions of personal interests” (Llewellyn, 2002, p. 16). Instead of learning passively, students take control of their learning – they ask their own questions, find ways to answer their questions or solve their problems, investigate, gather data and make their own conclusions based on their own observations (Llewellyn, 2002). While it may seem that learning through active participation is an obvious way that children learn, this has not always been the case in educational history.

Behaviorism prevailed as an educational theory in the 20<sup>th</sup> century (Llewellyn, 2002). Through research done by Edward Thorndike and B. F. Skinner, theories that behavior can be learned through practice and “operant conditioning” (Llewellyn, 2002, p. 41) began to place an important role in education. According to the behaviorist theory, a student’s learning may be measured through the student’s behavior (Llewellyn, 2002).

Constructivists have existed for some time. However, the movement did not gain much momentum until John Dewey (1859-1953) advocated for its use. The core of the constructivist theory is that “each learner needs to make use of knowledge for it to be

meaningful and retained” (Llewellyn, 2002, p. 42). Inquiry is considered constructivism as it serves as a way for students to make connections to science and then be retained for future use (Llewellyn, 2002).

Many people think of labs when thinking of inquiry because labs give students tangible evidence of scientific concepts. However, lectures, demonstrations, and case studies all play an important role in the classroom and can also be inquiry-oriented. In general terms, lectures can be “an effective means for introducing a unit, clarifying understandings, and defining science terms” (Chiappetta & Koballa Jr., 2002, p. 108). In order to increase inquiry in my classroom, I often shape lectures for that purpose.

Lab learning, as Jean Dickey said, promotes activities that can help clarify and increase lecture material as well as develop connections to the material. However, Dickey stated, “‘hands-on’ should be accompanied by ‘minds-on’” (1995, p xiii). Science becomes more than trivia memorization; it becomes an investigation process using universal skills.

Science labs benefit student learning in ways that lectures simply cannot. One benefit of labs is a thought process, “the potential to engage . . . in authentic investigations in which they can identify their own problems to investigate, design procedures, and draw conclusions” (Chiappetta and Koballa, Jr. 2002, p. 150). In a way, learning inquiry in the laboratory is like knowing how to read a map instead of blindly following a GPS. Teachers can give students micro managed directions to follow mindlessly, or can teach them to be engaged and read an actual map—teach them how to get themselves from one place to another (Dickey, 1995).

Many studies have been conducted in science classrooms. In looking at some of these studies, I found several research instruments that aided my own research.

Comparing pretests and posttests to measure growth as well as using questionnaires to measure attitude were means of data collection in several studies. Olsen (2009) studied differentiated instruction. In one area of testing, Olsen used similar data collection and analysis that I will be using in my own action research. Olsen had her students complete an “Astronomy Unit Preassessment” and after the assessment, she had them complete the “Astronomy Unit Postassessment” (2009). These assessments were not on content, but rather about the students' own feelings about group work to determine if her differentiated instruction was making a difference.

Rosillo (2007) also used pre and post assessments in her capstone project to track the students' progress through her study about traditional vs. inquiry-based units of instruction. While I had never been a big fan of pretests as a student or a teacher, I was anxious to see how pretests used in this context would determine the growth of the students throughout the treatment. One of my goals in my action research was to see how well my students could connect the lecture to the lab. Comparing pre and post test results of a traditional unit to an inquiry unit, I could actually measure which methods yield more student gains.

Olsen's (2009) collection of data was also very similar to Ornstein's (2006). Ornstein used a questionnaire to determine the students' attitudes towards science. In addition to an attitude survey, he also gave questions about the frequency of certain aspects in inquiry science, such as “how often do you . . . carry out scientific experiments yourself . . . test predictions” (2006, p. 289). Ornstein then compares the attitudes that the

students had towards science between students in classrooms with high-use of inquiry and classrooms with low-use of inquiry. Likewise, I used a questionnaire and survey given before my research began to determine the attitudes of my students. Instead of comparing between different classrooms, I looked for any attitude change after the treatment was finished.

Mathot (2009) conducted an action research study in his own classroom to see if inquiry activities helped students gain interest and actively participate in science. One of the conclusions he came to was that “inquiry-based labs do get students more involved and interest in doing science” (Mathot, 2009, p 41). In addition to getting more students involved, he also found that students preferred inquiry-based labs to cookbook labs. I had hoped to find similar results in my own studies on inquiry – not only that students will prefer inquiry-based labs but that they will also learn more from them.

## METHODOLOGY

### Treatment

My action research compared results of six units. Three units had treatments while three units remained without treatment. Each unit was between two and three weeks long with approximately one month between the treatment and non-treatment cycles. The non-treatment units included cellular structures, transport, and processes. The treatment units included Mendelian, complex, and molecular genetics.

Prior to my research, I often presented material to students through lecture followed by guided practice through the use of worksheets or text problems. Depending on the concept to be taught, I also included a lab or demonstration for topic

reinforcement. At the end of each unit, my students would hand in all of their assignments at once in a “notebook” (a coversheet with all assignments stapled to it) and then take a quiz over the material learned in the unit. Even though I did not provide feedback through grading their homework, I provided constant feedback throughout the chapter. My non-treatment units continued this same pattern.

My non-treatment began with labs on osmosis and fermentation. They also created a cell model, completed various case studies about osmosis and cellular structures, and created and performed a skit about photosynthesis. While case studies are a form of inquiry because they require students to ask questions and apply what they have learned, I included them in my non-treatment because I have done it in the past and found it worthwhile. These activities represented past activities and normal day to day teaching methods. These activities were completed in October, November, and December.

My treatment included two major changes to my teaching. The first change was the type and frequency of lab, changing from less frequent cookbook labs to more frequent guided inquiry labs. Some of the inquiry activities included in the treatment were new to my curriculum as signified by “new” in Table 1. Other activities were modified from the cookbook labs into more inquiry-oriented labs. These types of activities are indicated by “modified”. Table 1 shows the various labs and activities I included in my treatment, the unit they fell under, and the approximate time for completion.

Table 1  
*Treatment Activities*

<b>Treatment Unit</b>	<b>Activity Name</b>	<b>New/Modified Activity</b>	<b>Time (min)</b>
Molecular Genetics	Modeling Meiosis	New	50
	Homologous Shoes	New	15
	Tasting Genetics	Modified	25
	Predicting Probability in Genetics	New	20
Complex Genetics	Investigating Human Pedigrees	New	20
	Human Karyotyping	Modified	80
	Human Pedigree Work Sample	New	80
Molecular Genetics	Human DNA Model	New	10
	Model DNA Replication	Modified	15
	pGLO Lab	Modified	200

In labs from prior years done in my non-treatment units, my students followed a series of steps outlined in the lab, filled out the existing data tables, and answered questions to reinforce topics already learned. In my treatment labs, I first modeled the labs before the students completed them. Students completed the labs in pairs, according to assigned seating. In addition, the students created their own data table instead of filling out a pre-fabricated data table where applicable. I observed that modeling labs for the students helped them break away from just following a series of steps to becoming invested in the lab.

The second major change I made for my treatment was the inclusion of the reflective questions, “What did I do, see, and learn?” at the end of the lab as part of an informal lab write-up. In the past, I rarely have had my students complete a formal write-up where they identified variables, explained their results and why they got their results. Instead, the students graphed their results and answered a few questions at the end of the lab. In the treatment, I still did not require my students to specifically identify variables or describe all of the intricacies of the labs. Instead, I provided more inquiry-oriented questions for them to answer with their lab partners, and more engaging questions that probed about potential scenarios or advantages of certain genetic abilities etc. With this treatment, the students had the chance to reflect on their learning and the purpose of the lab. The end goal was to have students reflect and make connections between the lecture and the lab. One particular lab, the Human Pedigree work sample, was slightly different from the other labs in that I did require a formal write-up of their investigation. Like the other labs, however, the students were also asked the “what did I do, see, and learn?” questions.

### Research Design

I designed my research to use a variety of instruments; each instrument answering a specific research question. Formative assessments, summative assessments, pretests and posttests were the most common instrument for gathering data. In addition to these instruments, I also used surveys, interviews, and journaling to gather data on attitudes of the students and myself. The following table gives an overview of the instruments I used to answer my research questions.

Table 2  
*Data Collection and Research Methods*

Research Question	Data Sources		
To what extent can the inclusion of reflection strategies like “What did I do? What did I see? What did I learn?” increase student understanding of lab concepts?	Formative and summative assessments	Pretests and post-tests	Student and peer interviews
How does increased use of inquiry activities affect student attitude toward science and scientific inquiry labs?	Student Surveys	Student Interviews	Journaling
How does increased use of guided inquiry in the laboratory impact the teacher?	Journaling	Student interviews	Informal peer interviews

Formative assessments given during the treatment and non-treatment included labs as well as various classroom assessment techniques (such as concept mapping, summaries, categorizing grids, and muddiest point papers). Valuable data about student progress was gathered from the formative assessments. A total of 10 inquiry-based activities were given throughout the three treatment units. To lessen the amount of data analysis, I collected formative assessments from twelve students of varying ability—three who earned an A grade, three who earned a B grade, three who earned a C grade, and three students who earned a D grade. Of these twelve students, eight were males and four were females; eight were Hispanic, three were Caucasian, and one was African-American; five were in grade 9, six were in grade 10, and one was in grade 11. The various classroom assessment techniques were given at a rate of one or two per unit and data collected from the same twelve students.

The quizzes given at each unit's completion were used as summative assessments as well as post-tests. The same 12 students used for formative assessment collection were also used in this data collection. Data from the pretests and post-tests will show the growth of the students throughout the unit. Using the same students, comparisons were then made between the non-treatment units and the treatment units. Questions in the pretests were exactly the same as in the posttest – ten questions per unit, all multiple choice questions.

Student surveys and interviews were given to determine attitude and perspective towards science and learning science. Fifty-three biology students completed the Likert survey and explained their reasoning for each answer. This gave me a richer understanding of what the students meant when answering each question. The students involved in the survey came from various backgrounds of science. Seventeen of the students were in grade 9 and took biology because they were recommended by their middle school science teachers as students who excelled in science. These students were highly motivated and only one of the ninth graders earned below a B over the course of the year. These students will be expected to take chemistry next year. Thirty-three of the students were in grade 10 and had taken physical science the previous year. Some will go on to take chemistry – those who are planning on attending collage usually take this route. The students who do not want to take chemistry will take either environmental science or geology as their third year of science. The remaining three students were in grade 11. One student was retaking the class and the other two were a year behind because they were transfer students from Mexico. All three of the eleventh graders

demonstrated a good work ethic; two of them earned a high A grade. Like all of Nyssa High, all of my students were eligible for free lunch and breakfast.

Another useful data collection tool was conducting student interviews. They gave me the opportunity to ask probing questions about attitude and perception on the effectiveness of the treatment. More so, the students were able to expound about their thoughts regarding the reflective questions of “what did I do, see, and learn?” I interviewed ten students – three male and seven female. These students volunteered to be interviewed, and their answers are discussed in greater depth in the data analysis section.

Not only did the students answer the questions at the end of each lab in order to measure the effect of instating inquiry, but also the teacher. I completed entries following each lab to answer the following questions:

- 1) How did the students react to the lab?
- 2) If I could change how I presented the lab, what would I change?
- 3) What part of the lab seemed to drag?
- 4) How well were the students acting independently?

To conclude my thoughts about the lab, I wrote a brief reflection about concerning the lab and how it affected my research.

To ensure validity and reliability of the instruments, questions in the pretests and post-tests were kept the same within each unit. Doing so enabled me to compare the students’ grasp on exactly the same concept before and after the unit. Similar questions scattered throughout the survey also developed reliability. If the questions were indeed reliable, the answers the students gave were similar between the two questions. For example, two questions on my survey state, “I like to design my own labs” and “I learn

best when I design my own labs”. If the survey were reliable, the students would answer those two questions in a similar manner.

In another effort to ensure validity, I kept track of how many students missed each question across all of my biology classes. If there were a quiz question that 80% of the students answer the question incorrectly, it may not be measuring what it was meant to measure and therefore would be not valid. In addition to keeping track of the number of correct answers per question on the quizzes, I consulted with Ken Dickey, a fellow science teacher to see if my questions on the surveys and interviews were valid and measuring the intended concept.

One of the ways I collected data for my first question was by scoring the answers to the three questions “What did I do, see, and learn?” This gave me some longitudinal data that the CATs gave me in the non-treatment section. To glean information from the reflection section of the lab, I used a generic rubric to quantify the data. These reflection questions were meant to be answered quickly; the scoring is likewise. With the numerical score, I tracked their scores of the labs throughout the treatments to see if the scores improved with the frequency of guided inquiry labs. The generic rubric is shown below in Table 3.

Table 3  
*Generic Rubric for Scoring 3 Questions*

	5	3	1
What did I do?	Student shows they have an excellent grasp of what they did in the lab	Students convey they have a basic idea of what they did in the lab	Student was clearly lost as to what to do in the lab.
What did I see?	Student saw and made careful observations during the lab	Student saw and made okay observations during the lab	Students missed key observations or missed observations due to incorrect methods
What did I learn?	Student understood the main point of the lab and the biological concepts behind the lab	Student somewhat understood the concepts, but were missing some key points	Student shows a vague understanding of the lab concepts

Another instrument I used in my research was a biology attitudinal survey. This survey was implemented at the beginning of the non-treatment section and re-administered at the end of the treatment. The survey gathered the students' attitude towards science, how they feel they learn best, and their attitude towards the way a lab is structured. Following each question, the student was asked to explain their answer. A copy of the instrument is found in Appendix A. The research methodology for this project received an exemption by Montana State University's Institutional Review Board and compliance for working with human subjects was maintained.

## DATA AND ANALYSIS

I gathered data of my students' attitudes regarding biology and lab activities through the administration of the Biology Attitudinal Survey before any data was

gathered (Appendix A) and again after all the treatment was complete (Appendix B). Following each Likert-style question, the students briefly explained their answer. In addition to those questions, the students also completed short-answer questions.

All four of my biology sections (a total of sixty-five students, fifty-three of which were present for both surveys) took the Biology Attitudinal Survey.

Figure 1 below shows the number of responses for each selection on each question.

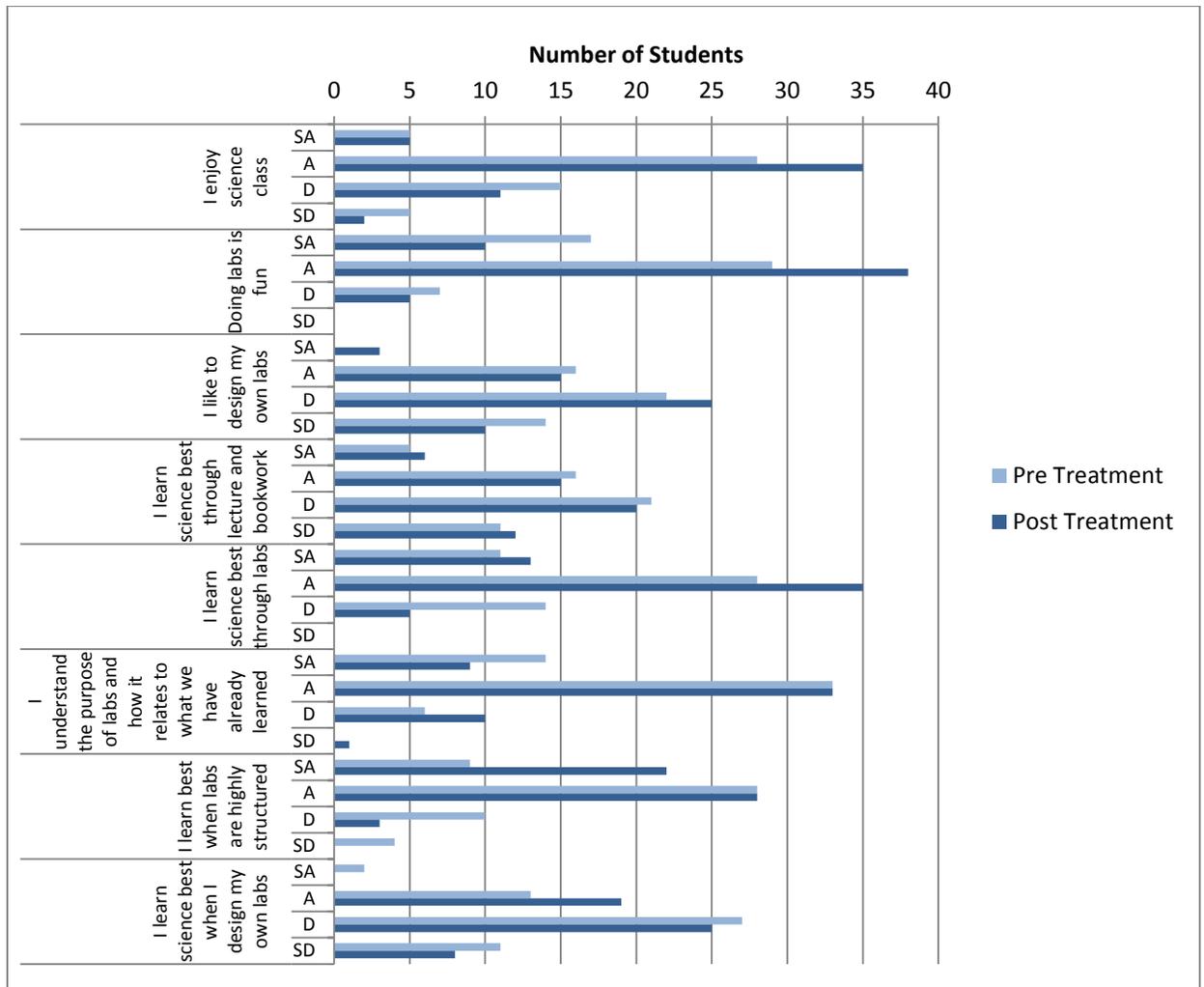


Figure 1. Biology Attitudinal Surveys, (N = 53)

The first pattern I noticed from this data was that students were more apt to select agree or disagree throughout the entire survey. Only 24% of the responses were from the strongly agree or strongly disagree category in the survey before treatment. The final survey had likewise the same results – only 26% picked strongly agree/strongly disagree throughout the survey. This indicates the majority of my students do not express extremely strong feelings in a positive or negative way towards biology.

In the first survey, I noticed that even if students did not enjoy science, they often selected a positive response to enjoying labs. Of the 20 students who did not enjoy science, 14 students selected that they enjoyed labs to some degree. For example, one student disagreed about enjoying science class. He wrote, “I lost interest in science.” Yet, on the second question where the survey states, doing labs is fun for me, the same student selected strongly agree and wrote, “I enjoy labs.” I think this means that even though students may not enjoy biology, they do enjoy rolling up their sleeves and getting some hands-on experience or possibly they may enjoy the time interacting with others. Another student selected disagree for enjoying science because he “never [does] good in . . . science classes,” yet he selected agree for about enjoying labs. It seems that students not only equate enjoying science with content, they equate enjoying science to how well they do in class.

The second survey also showed the same pattern. Seven of the eleven students who did not like science agreed that they enjoyed doing labs. Some of their responses were “Labs are okay but they are hard for me;” and “I learn so much more.” However, at least two students enjoyed labs because it was different from the daily note-taking and worksheet routine.

Not all students enjoyed doing labs, however. Before treatment began, only seven students selected that they disagreed to enjoying labs. In the post-treatment survey, the number decreased to only four students disagreeing to enjoying labs. Two of those students enjoyed labs at the beginning of the treatment but not at the end. Those two particular students both mentioned the labs were not fun anymore. Perhaps they enjoyed the labs towards the beginning of the year compared to the labs towards the end of the year. The other two students selected that they did not enjoy labs in both surveys. One of those students, a “C” student, said that doing labs “doesn’t really help me understand what we are doing!” The other student, who struggles to pass the class, wrote, “I don’t like labs because most labs I don’t know what I am doing.” It seems that students who struggle to understand the labs whether it is procedure or content do not enjoy the labs as much.

There may be several reasons why the students don’t understand the labs. One could be they struggle with biology in general. To then apply biological concepts in the lab may be a little bit difficult because they don’t understand biology in the first place. Another reason why the students may not understand the labs could be due to the actual lab itself. Some labs require meticulous procedures. These procedures may not make any sense if a student rushes through a lab and does not slow down for comprehension.

One student brought up an interesting point when he wrote, “Most labs are enjoyable but the ones recently have not been.” The inquiry labs and activities done for my treatment were not necessarily full-blown labs as the students did at the very beginning of the year, before even the non-treatment units were done. In my journal, I noted that “we did a couple of mini labs- they aren’t true inquiry labs, just ones I’ve

modified to be more inquiry-oriented.” This may be the source of that particular student’s comment.

Interviews with students also showed a trend of positive attitudes towards labs. I interviewed ten students – three males and seven females. Of these ten students, four of them were students who earned an A grade, two were students who earned a B grade, three were students who earned a C grade, and one was a student who earned a D grade. When asked what they enjoyed the most about biology, seven mentioned the labs. There were varying responses as to why they enjoyed science. One student said she enjoyed labs and they helped her to learn because “labs actually get you to see what you are doing.” Another student, one of the top students in all of my biology classes said, “[Labs] gives us a chance to explore. You tell us, but to actually do it actually sticks in your mind.” This student was also one of the few (only four out of fifty-three students) to select strongly agree on the survey when asked if she learned science best when designing her own labs.

An interesting pattern arose from a comparison of question two and three in the pre-treatment survey. In question two, 87% of the students marked that they either strongly agreed or agreed that doing labs is fun. In question three, only 30% agreed that they enjoyed designing their own labs and 70% disagreed or strongly disagreed with the statement. One student who liked labs but strongly disagreed with question three stated, “It’s no fun and I don’t really learn.” Another student, a female sophomore, wrote for question two, “It gives us a chance to do something other than bookwork,” and at the same time wrote an entirely different response for question three, “They are so boring and hard to decide what to do.” These findings are also shown in question seven (*I learn*

*best when labs are highly structured*) and question eight (*I learn science best when I design my own labs*).

The same pattern appeared in the post-treatment survey. However, there were two more students who selected a positive response to both questions about enjoying labs (91% of all student responses) and enjoying labs that were designed by them (34% of all student responses). The responses to self-designed labs on the second survey told some stories about how students view science and learning science. Table 4 below is a quick summary of the different patterns found in the survey responses.

Table 4  
*Designing Labs, (N = 50)*

	<i>Reason</i>	<i>Number of Responses</i>
	Own interest	5
Students like to design their own labs	Design aspect is enjoyable	4
	Better idea of what to do	3
	Get to find own results	2
	Apply self to subject	1
	Dislike design aspect	10
Students do not like to design their own labs	Difficulty understanding	8
	Rather follow directions	7
	Not fun	4
	Too much thinking	2
	Not enough results	1
	Too much time	1
	Do not like them	1
Not good enough at science	1	

One student who struggles to pass wrote, “I want to be able to pick something I’ll be very interested in. Another student had the same opinion; he wrote, “[it] allows me to do what I want to do, which helps me pay more attention.” Others liked to design their own labs but expressed concern about their ability. One female selected agree but wrote, “trying to find an experimental solution to a problem is really fun, but sometimes I feel as if I don’t know enough about the project.” I think that with enough practice, these students will gain confidence in designing their own labs.

The negative responses also showed a myriad of reasons why they did not like to design their own labs. One female student wrote, “It would be okay if I knew a lot about the thing and [then] made up a lab,” hinting that the reason she did not like to design her own labs was that she did not know enough about the lab. One student who disagreed with the survey statement wrote, “I don’t like doing my own labs because normally they aren’t fun.” Yet another statement from a student who usually squeaks by with a “C” in class wrote, “Too much work for me, it’s the teachers job!” Some of the students apparently thought I should provide everything for them so they would only have to do the steps and not learn how science actually is carried out!

Question four (*I learn science best through lecture and bookwork*) shows some interesting data. The responses to this question did not change much from the before-treatment survey and the after-treatment survey. Overall, 62% (60% after-treatment) of the students said they disagreed with the statement while the remaining 38% (40% after) agreed with the statement. One of my students identified as a possible Talented and Gifted student wrote, “No! [bookwork] gets boring, so sometimes I don’t do it.” Another student who struggled in my class simply circled “agree.” It showed that learning ability

was not necessarily reflected in learning style. Table 5 shows the breakdown of the students' responses by performance level.

Table 5  
*Learning Style by Grade Performance, (N = 53)*

		Number of students by semester grade			Total number of students
		A	B/C	D	
Agree (learn best through lecture and bookwork)	Pre-treatment	8	9	3	20
	Post-treatment	7	11	3	21
Disagree (do not learn best through lecture and bookwork)	Pre-treatment	8	16	9	33
	Post-treatment	9	15	8	32

The responses also showed a variety of reasons why or why not they learned best from book work. One student said “I sort of learn from bookwork, but overall it just bores me so I don’t pay attention.” Another student, one of the top freshmen in class, also wrote, “I learn by taking notes and watching and listening to videos and lectures. It really makes things more understandable. Even students who do not excel in biology had a variety of reasons as to why or why not they learned best through bookwork. One “C” average student classified as a migrant student wrote, “I agree because for me if I read it and look at some of the examples given, I learn more.” This data shows there is a need for a variety of learning methods because each student is unique. In a classroom setting, this means lecture, bookwork, inquiry activities, and group activities all need to be incorporated together to help all student learning styles. Teaching students about osmosis, for example, can be taught through lecture first, an inquiry oriented lab second and finally followed up with written work to help solidify the concepts.

Prior to each unit, both during the non-treatment and the treatment, the students took a pretest. All pretests were ten questions long. At the end of the unit, the pretest became the first ten questions in the unit quiz. The data I collected from these pretests and quizzes came from my first and sixth period classes in order to simplify the data collection. These two classes have a fairly good mix of students, although they tend to be among my better students. The demographics of these two classes (total of 32 students) are summarized in Table 6 below.

Table 6  
*Demographics for Biology Students, (N = 32)*

Demographics	Category	Number of Students
Grades (at the end of Semester 1)	A	12
	B	6
	C	6
	D	8
	F	0
Ethnicity/Race	White	13
	Black	1
	Hispanic	17
	Native American	1
Grade Level	9 <sup>th</sup> grade	15
	10 <sup>th</sup> grade	15
	11 <sup>th</sup> grade	1

I compared scores from the pretest to the same questions given on the quiz in an effort to see if progress made during the treatment increased. The scores are summarized in *Figure 2* below.

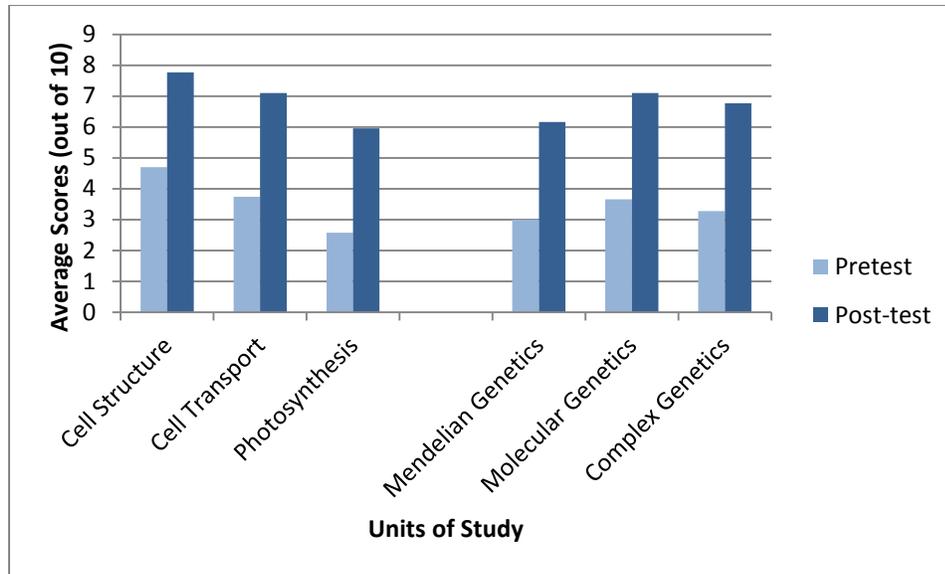


Figure 2. Student Pretest and Quiz Scores, (N=30)

The average of the quiz scores for the treatment (6.68/10) is slightly less than the quiz scores of the non-treatment (6.94/10). There may be several reasons for this statistic. First, the average pretest scores of the non-treatment are higher than those of the treatment – 3.67/10 compared to 3.31/10. The material itself in the treatment units may have been less familiar to the students or the students may have thought it more boring. It is difficult to pinpoint an exact reason with the data available. Second, there is always the problem of trying to compare scores of different units to each other. It was at a different time of year, students may have become bogged down with other classes etc. A lot of my students were involved in sports that had late practices which may have factored into student performance.

In addition to gathering quiz scores from all 32 students, I also tracked 12 specific students, each with varying ability to see how they progressed through the treatment. Their demographics are summarized in Table 7. In addition to the information in the table, this group of students has one student who recently came to the United States within the last two years and one student who is on an IEP.

Table 7  
*Demographics of Tracked Students, (N = 12)*

Demographics	Category	Number of Students
Grades (at the end of semester 1)	A	3
	B	3
	C	3
	D	3
	F	0
Ethnicity/Race	White	3
	Black	1
	Hispanic	8
	Native American	0
Grade Level	Grade 9	5
	Grade 10	6
	Grade 11	1

The students tracked show some very interesting patterns. I first took a look at the average quiz scores by the grade the students earned in class. *Figure 3* illustrates the trend. Overall, the average for all 12 students prior to treatment was a score of 6.63 correct out of 10 questions. For the quizzes taken during the treatment, the average for all 12 students was 6.15 out of 10. This shows a slight decline in performance despite the treatment. One reason for the slight decline may be due to the material studied in the treatment. The students may not have been as familiar with the material as they were with the non-treatment material.

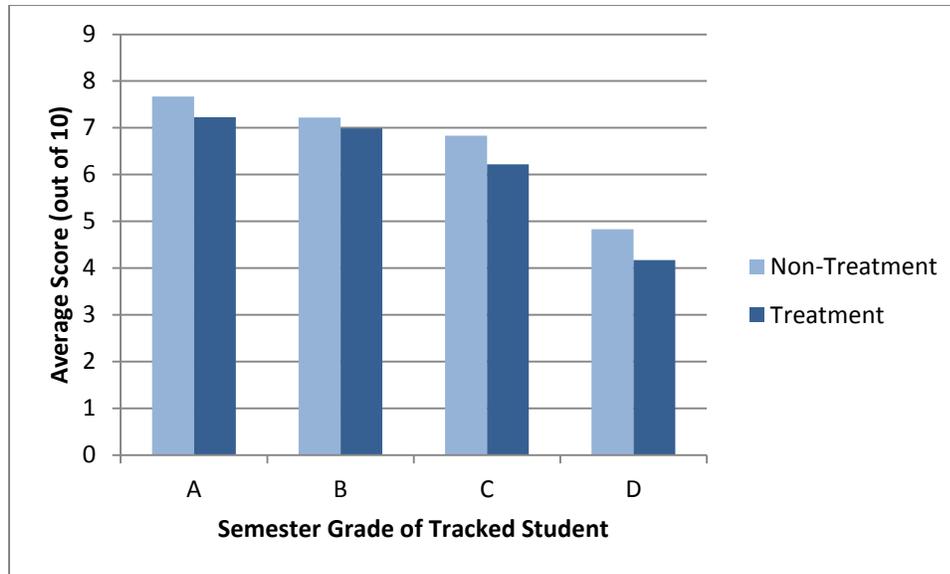


Figure 3. Average Quiz Scores for Tracked Students, ( $N = 12$ )

As mentioned earlier, it is difficult to decipher the exact reason the scores for the treatment went down instead of up as hoped. In effort to understand the scores a little bit more, I found how much each student gained in score by subtracting the pretest scores from the quiz scores. The results are seen below in *Figure 4*.

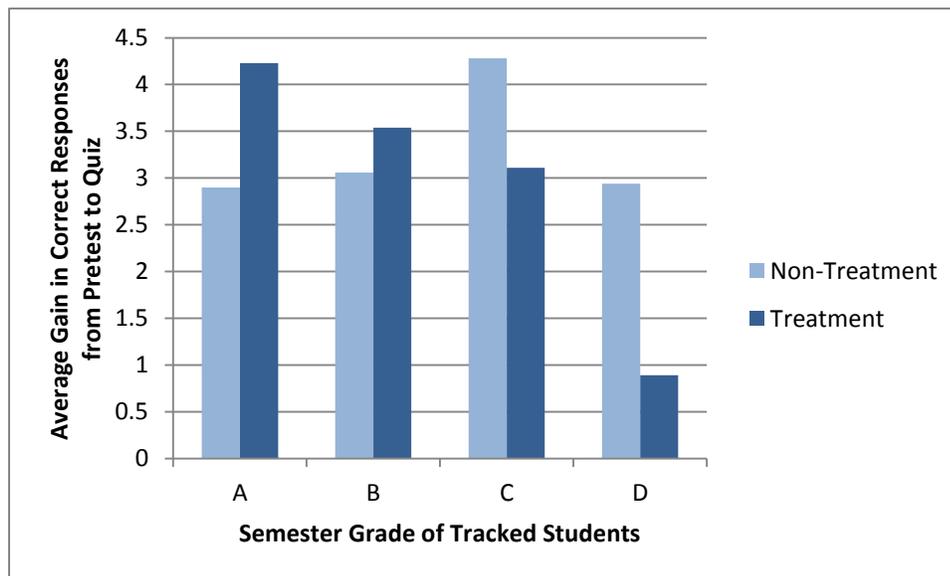


Figure 4. Average Gain of Tracked Students, ( $N = 12$ )

This graph shows that the A students went from increasing an average of 2.9 points to an average of 4.2, the most gain of the students tracked. The B grade students

also increased their average gain of 3.1 to 3.5. Unfortunately, both the C grade and the D grade students did not experience any gain. In fact, they went down. The C grade students decreased from an average of 4.3 points gained to 3.1 points gained. The D grade students decreased even further, going from a 2.9 increase to a .9 increase. This decrease shows the D grade students did not understand the material in the treatment units. When comparing the pretests to the post-tests for the D grade students, it was apparent the students were guessing on most questions. There were questions they would mark correctly on the pretest but then answer incorrectly on the quiz. These results for C and D students strongly indicated that further research is needed to determine the cause of the grade decline. It is possible that inquiry is unhelpful to students of certain learning styles, foundation knowledge, or motivation. More research is needed for any firm conclusions.

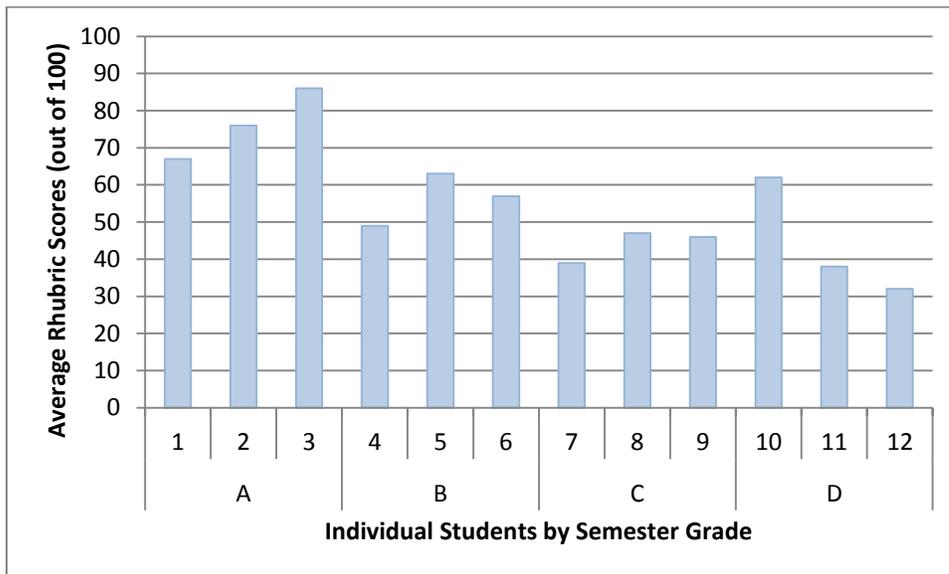
Following each inquiry activity throughout the treatment, the students had to answer the questions, “What did I do? What did I see? What did I learn?” I used the following rubric to score the students’ answers.

Table 8  
*Generic Rubric for Scoring 3 Questions*

	5	3	1
What did I do?	Student demonstrates excellent grasp of the lab experiment	Student demonstrates adequate understanding of the lab experiment	Student clearly had little understanding of the lab experiment
What did I see?	Student saw and made careful observations during the lab	Student saw and made adequate observations during the lab	Student missed key observations or missed observations due to incorrect methods

What did I learn?	Student understood the main point of the lab and the biological concepts behind the lab	Student somewhat understood the concepts, but was missing some key points	Student shows a vague understanding of the lab concepts
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The data gathered shed light on some interesting trends. To analyze the data, I totaled each student's score for each inquiry activity. Then I found the average for each student and made it a percentage in order to alleviate differences in students missing one or two activities. For example, one of the B grade students had a total of 85 points out of a total of 150 points possible from all of the inquiry rubric scores. Her average score out of 100 was a 57. *Figure 5* shows each individual, in their grade range, and the average scores out of 100 for the average of all activities.



*Figure 5.* Activity Averages, ( $N = 12$ )

In general, the students who did better on the reflective questions were the same individuals who did well in the class overall. A few outliers do exist. One of the D grade students, a female who struggles with English and has been identified as a potential

candidate for an IEP has some very good summaries following activities. For example, one of the inquiry activities involved the students creating a human chain of DNA – this student summed up the activity and what she learned quite well. She wrote, “The DNA always pairs with the other side but their (*sic*) opposite ways.” This idea of antiparallelism is difficult to teach, but she understood the concept at the time of the lab.

Another stand-out was one of the B grade students. This particular student consistently wrote very short answers that did not show what he knew. In the Tasting Genetics lab, students tasted different pieces of paper to determine if they had the genes to taste the different chemicals. Some students could taste them, others could taste but tasted a different taste (i.e. salty vs. sweet). When answering the question about what he learned, this student wrote, “that different people taste different things.” It was a short answer but had I talked to him, he would have been able to tell me much more. I also happened to interview this student and asked him what he thought about the reflective questions at the end of the lab. In the interview, he felt the questions did not help him because he did not “really like that . . . stuff.” When asked how he learned the best, even though he enjoyed the labs the best, he felt that the “reviews right before the test” helped him learn the best.

This idea that the questions are redundant or silly may have played a role in some of the students’ answers. In the second survey, I included an additional question asking the students if the questions following the lab help them to understand the scientific concepts of the lab. While this question includes more than the reflective questions, there was still an interesting array of student responses. *Figure 6* gives a graphical

representation of the responses the students gave to the statement, “Questions that follow labs often help me to understand the scientific concepts of labs.”

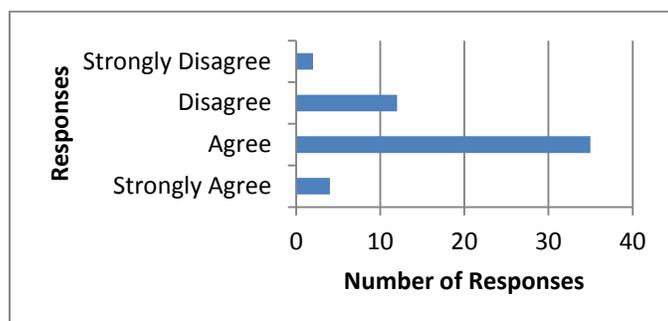


Figure 6. Question 9 Responses, ( $N = 53$ )

As seen in the graph, the majority of the students, 39 out of 53 agreed or strongly agreed that the questions at the end of the labs helped them. One student wrote that the questions “gives me a chance to review and look back to see what I did.” Other students had similar feelings. One wrote, “then the questions make you think about what you just learned,” while another wrote “questions actually make me think about what I did.” However, not all students felt the questions were worthwhile. One student who regularly maintained a B average stated, “Some questions help, other are sometimes pointless, because I don’t see how they are relevant to what we learned.” One of students who struggled in science also agreed with that statement. She added, “no, [I do not agree] because I know what I did so why talk more about it.” Another student did not find the questions helpful because she “honestly [did not] understand the questions most of the time.” While most students agreed the questions were helpful, some felt they had no point or they did not understand them.

To learn a little bit more about how the students felt about the reflective questions specifically, I asked the students I interviewed to tell me in their own words the purpose

of the reflective questions. Then I followed up by asking them how well they thought those questions helped them understand the purpose of the lab and remember it later on. The students gave mixed results. Seven students said it helped to some degree. One student said, the questions “help us to know what we did and then it wasn’t just a lab to do something, it was to learn.” Another student said “they kind of help, [the questions] made you go back and think a bit more about the lab and what you actually did learn from it. I asked this student if there was a difference in her labs having these questions. She responded that before, “you’d go through [the lab] and I’d remember stuff before, but to actually think more about it; like what did I do and learn from it to make that connection was different.”

However, not all responses were positive. In addition to the B grade student who knew that one reason for the questions was “for [the teacher] to figure out if we are learning or not” but felt they did not help him because he was not one for summaries, there were a couple of other students who did not like the questions. One female student, who also responded that she did not like science at all said, “it was just like repeating yourself- like, what’s the point?” Another student, one who works hard to earn a low A, said, “it was just something we had to do.” She did not see much value in answering the reflective questions.

Another interesting trend in the data collected from the reflective questions rubrics was the labs themselves showed a variety of scores for each one. *Figure 7* shows how the students’ average scores for each lab.

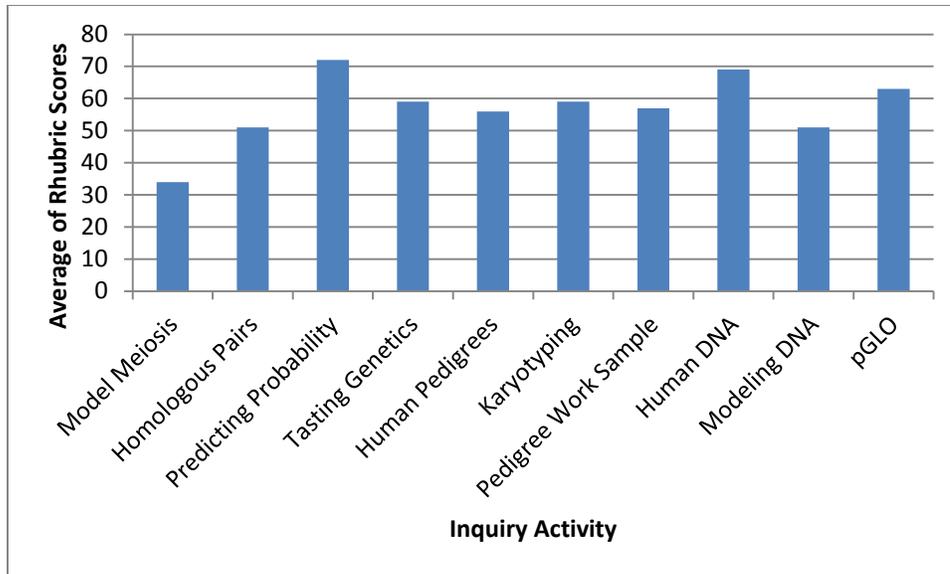


Figure 7. Average Scores for Inquiry Activities, ( $N = 12$ )

Modeling Meiosis was the first inquiry-type activity done for the treatment. It was a confusing lab, one I had not taught before. In my journal, I wrote, “A lot of students . . . were bored with the lab—they enjoyed playing with the string but not so much the regular lab portion. . . . It seemed the students were very dependent on me!” In addition to the students being bored, this lab was done right after the Christmas Break – the students forgot about mitosis, which they had learned about before Christmas. They also did not have much background on meiosis. So, it is no surprise this lab had the lowest rubric scores (an average of 34/100). The students also had not answered the reflective questions, so they struggled to determine what was expected in the questions.

As the treatment went on, the scores improved, but then leveled out around the 55-60 average range. It is interesting to note that some of these labs were specifically mentioned by the students I interviewed. At least two students mentioned the Human Pedigree as one of their favorite labs of the year. One girl discovered that her “whole family can roll their tongue like a taco.” Three students mentioned the pGLO lab where they transformed bacteria into bacteria that could glow under ultra violet light as being

some of their favorite labs because “it was pretty fun.” While these two activities did not have the top rubric scores, they did close to and better than the average rubric score of 57/100.

Even though the scores do not show that the students performed better in units with inquiry activities, as a teacher I felt the students had a better grasp of the information. Throughout the non-treatment, I constantly found ideas for changing the labs I did into inquiry labs for next year. Next year, the gummy bear lab where students explore the effects of osmosis will be much more inquiry oriented. I will have the students come up with their own way to show hypotonic and hypertonic solutions. They will also have to find their own way to measure the change in mass instead of pointing them directly to the balance.

Throughout the teaching journal entries during the treatment, I found myself wishing I had a better foundation in inquiry basics, such as making data tables. For instance, in the tasting genetics lab I wrote that “getting the students to create the data table!” was by far what seemed to drag the most in that particular lab. I also found myself in want of more time. In the Human DNA activity, I wrote, “If I had more time, I would perhaps make it more inquiry oriented and tell the students they need to come up with their own way to model DNA.” I think that as the foundations of inquiry are built towards the beginning of the year with heavily guided practice, the time issue will lessen slightly as the students will be able to work without as much directed instruction.

In summary, there was a slight increase in students who enjoyed science following the treatment units. In addition, there were more positive responses to learning through labs and designing their own labs. Students did not show an increase in quiz

scores following the treatment, although when broken down by grade level, the students had greater gains in the treatment sections than the non-treatment sections.

### INTERPRETATION AND CONCLUSION

The purpose of my research was to increase the quality and frequency of inquiry-based labs in my classroom and determine its impacts on student learning. I included the reflection questions “What did I do? What did I see? What did I learn?” to see if student understanding of biological concepts was increased. Overall, average scores on the quizzes decreased by six percent after the treatment. There could be any number of reasons for the slight decrease in scores – the content may have been less familiar, more difficult for students, or less concrete. The time of year may have been busier or more stressful for the students. The exact reasons are not known.

While the raw data of pretest scores and quiz scores did not show that the treatment increased test scores, upper level students experienced more gain between the pretest and quiz scores of the treatment than they gained during the non-treatment. The A grade students experienced a 45% increase in gain while the B grade students experienced a 16% increase in gain. Both C grade and D grade students did not gain as much in the treatment between the pretest and quiz (27% and 70% decrease in gain respectively).

For my first sub-question about the inclusion of “what did I do, what did I see, what did I learn?” as a tool to increase student understanding, I found that most students felt they helped them to learn. Seventy percent of the students I interviewed said the reflective questions were beneficial to them. The three questions “what did I do, what

did I see, what did I learn?” gave the student a chance to reflect on the lab and think about the purpose of the lab as a whole. However, these questions can become redundant, especially if the lab has specific questions for the students to answer prior to the reflective questions. While a powerful tool, these questions should not be used in every lab activity and every class demo. Instead, I will use these questions on larger inquiry lab activities and possibly as a test question in the summative assessments.

In conclusion for my second sub-question about student attitude, I discovered that student attitude also changed between the non-treatment and treatment. Before any research was conducted, 62% of the biology students enjoyed science. Following the treatment, 75% of the students enjoyed biology (21% increase of enjoyment in biology). The number of students who enjoyed doing labs also increased from 87% to 91% (four percent increase). The increased amount of inquiry activities and having labs for students to choose the direction of the lab helped increase the students’ positive attitudes as well. Although there was an increase in students who preferred structured labs (34% increase) there was also an increase in students who said that they learned best when they designed the labs (29% increase).

To answer the third sub-question about the impact inquiry has on the teacher, I am much more prepared and adept at including inquiry in the classroom. I have written down many ways to have more inquiry activities for next year. Following the gummy bear lab, which is designed to help students learn about and visualize osmosis, I wrote in my teaching journal, “I would rather the students find a way to measure the bears’ [mass] and create their own data tables,” as opposed to providing exact instructions and data tables for the students. Due to the nature of my capstone project and the timing of the

treatment and non-treatment, I was unable to immediately begin with inquiry activities this past year. With a chance to start the year fresh, a better foundation will be laid for my students to acquire inquiry skills and then become more independent in their investigations.

In addition to finding ways to redesign labs to make them more inquiry oriented and beginning the inquiry process earlier in the year, I also noted that my attitude towards inquiry changed. While in college, inquiry was discussed quite often. However, I remember being frustrated because there was no connection between the discussing and the doing, especially in biology. Many times the inquiry activities were for physical science and physics classrooms. Since doing my capstone project on inquiry, I have been able to find ways to get components of inquiry into activities. Sometimes these components were as small as the students creating data tables (which, I found, is difficult to teach!) or finding solutions to “what if” questions. For example, when learning about Punnett squares, it is easy for the students to complete a problem to cross  $a$  with  $b$ . However, when the “what if” is added into the equation, the students begin to explore the different possibilities that could result from various crosses. Even small components such as these add to the inquiry learning experience.

## VALUE

Throughout this entire process, I found that I looked forward to doing inquiry labs with my students and am excited about doing more inquiry labs next year. I also felt that the reflection questions were important to have on my labs. I wrote, “I like having the do, see, and learn questions, especially for the longer labs” as they slow the students

down long enough for them to think back on the lab and put into words what they learned. As more of my labs became inquiry oriented, my students became less dependent upon me. Following a lab on osmosis, I wrote, “At the beginning, the students were extremely dependent on me,” but as the students became more confident in what they were doing, they relied less upon me. Each cookbook lab I have done, I have begun to think of the lab as if it were an inquiry lab. What things would I change? How would I present the material? I recorded these ideas in my journal.

Through this process of implementing more guided inquiry into my classroom, I hope to shift even farther and have more pure inquiry in the classroom. My colleagues and I have had many discussions over the effectiveness and time it takes to do pure inquiry. While some feel it is not worth their time, I am hoping to show that once the students gain experience with guided inquiry and work towards pure inquiry, the chaos that seems to accompany activities like these will become a learning environment. One idea that came to me after the capstone project was to have the students design their own labs to test plant competition or test various abiotic factors (such as soil type) on plants. When students begin to experiment with something they have designed themselves, there is more ownership and excitement. In addition, it can also teach students about failure. When asked how he benefited from designing and carrying out his own experience, one student wrote, “I benefit from the experience of failing, this allows me to find a way not to do something.”

In addition to having an inquiry-oriented biology class, I want to extend the skills I will have learned through implementing inquiry in the classroom to my other science classes: environmental science and anatomy and physiology. While doing pure inquiry in

anatomy and physiology would be difficult, there is the potential to use case studies as the inquiry tool.

The research I did with inquiry brought up some questions. How will I teach basic inquiry skills so the students can be successful with unguided inquiry activities? How will I help students become excited in the process of learning? How will I teach my students that there is not always one right answer; that experiments need to be tried several times, that we don't always know what the outcome is supposed to be? What are some effective ways to teach reflection? What other types of meaningful activities can I incorporate into my curriculum? How much is enough inquiry? How much is too much inquiry? To begin answering some of those questions, I will begin by teaching with inquiry immediately. One activity in mind allows the students to change various factors with a slice of bread in an effort to grow mold. This lab will allow me to lay a foundation in inquiry skills and practices, hopefully smoothing the way for future labs.

In my non treatment cell unit, I really enjoyed the cell doctor activity. This activity gives students various situations of "patients" who have a malfunctioning organelle. To make it more inquiry oriented, I could have my students create their own scenarios for a "cell patient".

Not all of the activities I used for the treatment were successful. One particular lab, *Modeling Meiosis* was very difficult for my students. My students did this lab right after they got back from Christmas break and without any lecture beforehand. In the teaching journal I wrote, "A lot of students were bored with the lab – they enjoyed playing with the string but not so much the regular lab portion." While I tried to make this lab inquiry oriented and have the students explore for themselves how meiosis might

take place, I think that because it is such a complex process that more background information would be needed. This is a lab I would drastically change for next year, if I were to even use it at all. In the teaching journal, I wrote that instead of using string, I would use “magnetic beads, if I could get more colors of beads, it would be easier to see centromeres etc.” However, there are some extreme budget cuts taking place at my school right now, so the possibility of getting those beads might not happen.

Most of my activities were worthwhile and I will use them next year. However, I won't use the “what did you do, see, and learn” for all of my activities. I think those questions are best in actual labs. This will avoid mindless repetition and focus the students on the labs where focus is needed.

Overall, this experience has really opened my eyes to the possibilities and value of inquiry in the classroom. I am excited for next year to begin laying a foundation for my students and to help them learn to love to learn!

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APPENDICES

APPENDIX A

BIOLOGY ATTITUDINAL SURVEY 1

**Biology Attitudinal Survey** – Please circle the letter of the statement that *best* represents your view.

- |  |   |
|--|---|
| <p>1. I enjoy my science class</p> <p>a. Strongly Agree</p> <p>b. Agree</p> <p>c. Disagree</p> <p>d. Strongly Disagree</p> <p><b>1a. Explain your answer</b></p>                           | <p>a. Strongly Agree</p> <p>b. Agree</p> <p>c. Disagree</p> <p>d. Strongly Disagree</p> <p><b>5a. Explain your answer</b></p>   |
| <p>2. Doing labs is fun for me</p> <p>a. Strongly Agree</p> <p>b. Agree</p> <p>c. Disagree</p> <p>d. Strongly Disagree</p> <p><b>2a. Explain your answer</b></p>                           | <p>6. I understand the purpose of labs and how it relates to what we have already learned</p> <p>a. Strongly Agree</p> <p>b. Agree</p> <p>c. Disagree</p> <p>d. Strongly Disagree</p> <p><b>6a. Explain your answer</b></p> |
| <p>3. I like to design my own labs</p> <p>a. Strongly Agree</p> <p>b. Agree</p> <p>c. Disagree</p> <p>d. Strongly Disagree</p> <p><b>3a. Explain your answer</b></p>                       | <p>7. I learn best when labs are highly structured</p> <p>a. Strongly Agree</p> <p>b. Agree</p> <p>c. Disagree</p> <p>d. Strongly Disagree</p> <p><b>7a. Explain your answer</b></p>  |
| <p>4. I learn science best through lecture and book work</p> <p>a. Strongly Agree</p> <p>b. Agree</p> <p>c. Disagree</p> <p>d. Strongly Disagree</p> <p><b>4a. Explain your answer</b></p> | <p>8. I learn science best when I design my own labs</p> <p>a. Strongly Agree</p> <p>b. Agree</p> <p>c. Disagree</p> <p>d. Strongly Disagree</p> <p><b>8a. Explain your answer</b></p>                                      |
| <p>5. I learn science best through labs</p>  |   |

**Short Answer** – please answer the following questions as completely as you can (answer on the back)

9. Why do teachers give labs in science class?
10. Do you benefit from designing and carrying out your own experiment?
11. How well do you understand the purpose of the labs?
12. How well do labs help you to understand biology?

APPENDIX B

BIOLOGY ATTITUDINAL SURVEY 2

**Biology Attitudinal Survey** - Please circle the letter of the statement that *best* represents your view. Participation in this survey is voluntary. Choosing to participate or choosing to not participate in this survey will not affect your grade or class standing.

1. I enjoy my science class  
 a. Strongly Agree      b. Agree                      c. Disagree      d. Strongly Disagree

**Please explain your answer to question 1**

2. Doing labs is fun for me  
 a. Strongly Agree      b. Agree                      c. Disagree      d. Strongly Disagree

**Please explain your answer to question 2**

3. I like to design my own labs  
 a. Strongly Agree      b. Agree                      c. Disagree      d. Strongly Disagree

**Please explain your answer to question 3**

4. I learn science best through lecture and bookwork  
 a. Strongly Agree      b. Agree                      c. Disagree      d. Strongly Disagree

**Please explain your answer to question 4**

5. I learn science best through doing labs  
 a. Strongly Agree      b. Agree                      c. Disagree      d. Strongly Disagree

**Please explain your answer to question 5**

6. I understand the purpose of labs and how it relates to the what we have already learned. In other words, I come away from labs knowing and understanding the scientific concepts that were the reason for the lab.  
 a. Strongly Agree      b. Agree                      c. Disagree      d. Strongly Disagree

**Please explain your answer to question 6**

7. I learn best when labs are highly structured – the kinds of labs where every step is outlined for me.  
a. Strongly Agree      b. Agree      c. Disagree      d. Strongly Disagree

**Please explain your answer to question 7**

8. I learn science best when I design my own labs  
a. Strongly Agree      b. Agree      c. Disagree      d. Strongly Disagree

**Please explain your answer to question 8**

9. Questions that follow labs often help me to understand the scientific concepts of labs.  
a. Strongly Agree      b. Agree      c. Disagree      d. Strongly Disagree

**Please explain your answer to question 9**

**Short Answer – please answer the following questions as completely as you can**

10. Why do teachers give labs in science class?
11. In what ways do you benefit from designing and carrying out your own experiment? In what ways do you not benefit from designing and carrying out your own experiment?
12. How well do you understand the purpose of labs – meaning, when you have completed a lab, do you come away from the lab with a better understanding of the biology? Do you understand the scientific concepts of how the lab fits together? Do you understand the big picture the lab is getting at?
13. How well do labs help you to understand biology? Explain your answer.

APPENDIX C

CELLULAR STRUCTURE PRETEST AND QUIZ

**Cell Structure Pretest and Quiz**

1. What is the mitochondria's job?
  - a. control center
  - b. modify package proteins
  - c. make ATP
  - d. store waste products
  
2. What is the function of the nucleus?
  - a. control center
  - b. modify package proteins
  - c. make ATP
  - d. store waste products
  
3. What is the function of the Golgi apparatus?
  - a. control center
  - b. modify package proteins
  - c. make ATP
  - d. store waste products
  
4. Where are proteins made?
  - a. ribosome
  - b. centriole
  - c. nucleus
  - d. chloroplast
  
5. This small organelle removes junk and cleans up old organelles
  - a. ribosome
  - b. centriole
  - c. lysosome
  - d. rough endoplasmic reticulum
  
6. A cell with a cell membrane, cell wall, cytoplasm but no nucleus would be a(n)
  - a. plant cell
  - b. animal cell
  - c. eukaryotic cell
  - d. prokaryotic cell
  
7. The chloroplast
  - a. uses sunlight energy to produce food molecules
  - b. is found only in animal cells
  - c. is where proteins have carbohydrates and lipids added to them
  - d. contains the cell's genetic information
  
8. A certain cell contains a cell membrane, a nucleus, mitochondria, centrioles, and lysosomes. What type of cell is it?
  - a. prokaryotic
  - b. plant
  - c. animal
  - d. prison
  
9. Which of the following statements is **not** a part of the cell theory?
  - a. All living organisms are made of cells
  - b. Cells are the most complicated structure in living things
  - c. Cells come from preexisting cells
  - d. Cells are the basic unit of structure and function in living things
  
10. Of the following examples of cells, which is eukaryotic?
  - a. cell from a mushroom
  - b. *Staphylococcus*
  - c. *E. coli*
  - d. bacteria

APPENDIX D

CELLULAR TRANSPORT PRETEST AND QUIZ

## Cellular Transport Pretest and Quiz

Name \_\_\_\_\_

1. Which of these is NOT a function of the cell membrane?
  - a. provide structure
  - b. cell identification
  - c. keeps everything out
  - d. regulate what goes in and out of the cell
2. The movement of water across a semi-permeable membrane is
  - a. diffusion
  - b. osmosis
  - c. active transport
  - d. endocytosis
3. The cell membrane is mainly made of
  - a. phospholipids
  - b. protein pumps
  - c. free-moving proteins
  - d. carbohydrate chains
4. A substance that moves across a cell membrane without using energy tends to move
  - a. nowhere-it doesn't move because it is diffusion
  - b. away from the area where it is less concentrated
  - c. towards the area where it is more concentrated
  - d. towards equilibrium (away from areas where it is highly concentrated)
5. Particles that diffuse through the membrane through a protein are demonstrating
  - a. active transport
  - b. facilitated diffusion
  - c. phagocytosis
  - d. osmosis
6. Which of the following is **not** an example of active transport?
  - a. endocytosis
  - b. sodium-potassium pump
  - c. osmosis
  - d. phagocytosis
7. Ben applies too much fertilizer to his lawn. Before long, it "burns". This would be an example of \_\_\_\_\_.
  - a. hypertonic solution
  - b. hypotonic solution
  - c. isotonic solution
8. Theresa was severely dehydrated and then drank too much tap water. She was hospitalized. This would be an example of \_\_\_\_\_.
  - a. hypertonic solution
  - b. hypotonic solution
  - c. isotonic solution
9. Most IVs have a solution in them to match the fluids in your body. This would be an example of \_\_\_\_\_.
  - a. hypertonic solution
  - b. hypotonic solution
  - c. isotonic solution
10. Which of the following is **not** an example of homeostasis?
  - a. shivering when you are cold, sweating when you are warm
  - b. osmosis and diffusion
  - c. keeping blood sugar levels steady
  - d. all of these are examples of homeostasis

APPENDIX E

PHOTOSYNTHESIS PRETEST AND QUIZ

## Photosynthesis and Cellular Respiration Pretest and Quiz

- Which of the following are autotrophs?
  - owls
  - mushrooms
  - onions
  - rabbits
- Where does photosynthesis occur?
  - chloroplast
  - mitochondria
  - Golgi apparatus
  - nucleus
- In addition to light and chlorophyll, photosynthesis requires
  - water and carbon dioxide
  - oxygen and carbon dioxide
  - water and oxygen
  - water and sugars
- A total of 36 molecules of ATP are produced from 1 molecule of glucose as a result of
  - cellular respiration
  - glycolysis
  - alcoholic fermentation
  - lactic acid fermentation
- Which of the following best describes cellular respiration?
  - oxygen is a product
  - chloroplasts are needed for it to occur
  - a form of nutrition in autotrophs
  - energy is supplied to all cells
- One disadvantage to fermentation is that
  - it requires oxygen
  - it is a slow process
  - it causes painful side effects
  - it only lasts for a couple of seconds
- The leaves of a plant appear green because chlorophyll
  - reflects blue light
  - absorbs red light
  - does not absorb green light
  - absorbs green light
- Which of the following process would require oxygen?
  - Aerobic respiration
  - Anaerobic respiration
  - Fermentation
  - Both B and C
- Which process best describes how bread rises?
  - lactic acid fermentation
  - cellular respiration
  - glycolysis
  - alcoholic fermentation
- The process that releases energy from food in the presence of oxygen is
  - synthesis
  - cellular respiration
  - photosynthesis
  - fermentation

APPENDIX F

MENDELIAN GENETICS PRETEST AND QUIZ

## Mendelian Genetics Pretest and Quiz

1. If a cell has 12 chromosomes, how many chromosomes will each of its daughter cells have after **meiosis**?  
a. 4                      b. 6                      c. 12                      d. 24
2. A human diploid cell has  
a. 0 chromosomes    c. 46 chromosomes  
b. 23 chromosomes    d. 92 chromosomes
3. Homologous pairs are  
a. identical copies of the same chromosome  
b. slightly different copies of the same chromosome  
c. for each chromosome, one copy came from the mom, one from the dad  
d. both b and c
4. If cattle have 30 pairs of chromosomes, how many chromosomes are in their gametes?  
a. 15                                      b. 30                                      c. 60                                      d. 120
5. The physical characteristics of an organism (what it looks like) are its  
a. genetics                                      b. heredity                                      c. phenotype                                      d. genotype
6. True breeding is the result of plants that  
a. cross pollinated and produced offspring identical to themselves  
b. self pollinated and produced offspring identical to themselves  
c. cross pollinated and produced offspring different than themselves  
d. self pollinated and produced offspring different than themselves
7. Different forms of genes are called  
a. gametes                                      b. somatic cells                                      c. genotypes                                      d. alleles

*A purebred brown-eyed man is married to a hybrid brown-eyed woman. Let "B" be the symbol for the brown-eye causing gene; "b" be the symbol for the blue eye causing gene.*

8. What is the phenotype of the woman?  
a. brown eyed    c. blue eyed  
b. BB    d. Bb

*In pea plants, the gene for stem height has two alleles. The tall stem is dominant over the short stem.*



APPENDIX G

COMPLEX GENETICS PRETEST AND QUIZ

**Complex Genetics Pretest and Quiz**

Name \_\_\_\_\_

**In some chickens, the gene for feather color is controlled by codominance. The allele for black is  $C^B$  and the allele for white is  $C^W$ . The heterozygous phenotype is known as erminette.**

- If two erminette chickens were crossed, what is the probability that they would have a black chick?
  - 0%
  - 25%
  - 50%
  - 75%
- If a black chicken was crossed with an erminette chicken, what is the probability of producing a black chick?
  - 25%
  - 50%
  - 75%
  - 100%

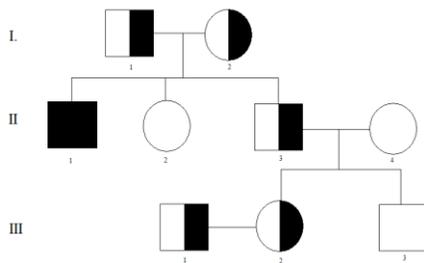
**A red snapdragon flower was crossed with a white snapdragon flower. Its offspring were 100% pink.**

- What type of inheritance do the snapdragons show?
  - multiple alleles
  - polygenetic traits
  - co-dominance
  - incomplete dominance

**Human blood types are controlled by three alleles,  $I^A$ ,  $I^B$ ,  $i$ .**

- Is it possible for a man with type AB ( $I^A I^B$ ), married to a woman with type A ( $I^A i$ ) to have a child with type O?
  - Yes
  - No
- What could explain a human karyotype showing 47 chromosomes?
  - monosomy
  - trisomy
  - codominance
  - dominant traits
- Why does nondisjunction occur?
  - Cytokinesis does not occur properly
  - The nucleoli do not disappear properly
  - The sister chromatids do not separate.
  - The chromosomes do not condense

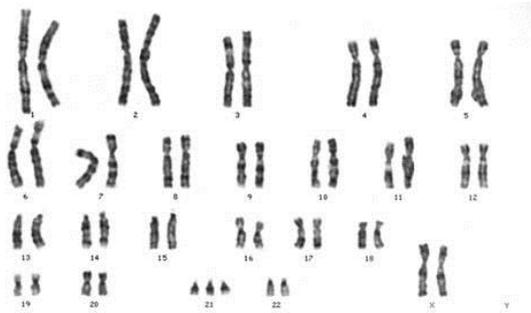
**Use the pedigree below to answer questions 7-8**



- Which person could develop symptoms of the disease that is tracked in the pedigree?
  - I-1
  - II-1
  - II-2
  - III-2

8. According to the pedigree, who is a carrier and cannot have children with the disease?  
 a. I-1                      b. II-1                      c. II-3                      D. III-1

*Use the photo below to answer question 9*



9. What disorder can be identified in the karyotype?  
 a. Turner's syndrome      b. Klinefelter's syndrome      c. Down syndrome      d. The karyotype shows no disorder
10. What determines gender in humans?  
 a. The X and Y chromosome      b. Chromosomes 21      c. codominance  
 d. epistasis

APPENDIX H

MOLECULAR GENETICS PRETEST AND QUIZ

## Molecular Genetics Pretest and Quiz

- DNA is composed of
  - deoxyribose
  - nitrogenous bases
  - phosphate groups
  - all of these
- RNA (is)
  - a protein
  - single stranded
  - made of ribinose
  - contains thymine
- DNA replication is best described as
  - Copying DNA onto a strand of RNA
  - Decoding RNA into DNA
  - Translating codons from mRNA into amino acids
  - DNA making another copy of itself
- The process by which the genetic code of DNA is copied into a strand of RNA is called
  - translation
  - transcription
  - transformation
  - replication
- Which of the following statements describes **translation**?
  - DNA makes another copy of itself prior to cell division
  - Re-writing DNA onto mRNA
  - Bases from the mRNA are decoded to make an amino acid chain.
  - RNA is used to make two strands of DNA
- Changes in the DNA sequence that affect genetic information are known as
  - mutations
  - replications
  - transformations
  - prokaryotes
- The type of RNA that takes an amino acid to the ribosome to be added to an amino acid chain is
  - mRNA
  - rRNA
  - iRNA
  - tRNA
- Which of the following accurately describes how bases are paired up in DNA?
  - adenine and thymine, cytosine and uracil
  - thymine and guanine, cytosine and adenine
  - adenine and cytosine, guanine and thymine
  - adenine and thymine, guanine and cytosine
- Bacteria often contain small circular molecules of DNA known as
  - clones
  - restriction enzymes
  - plasmids
  - hybrids

10. In cystic fibrosis, the amino acid phenylalanine is missing. What type of mutation is this?
- a. Substitution
  - b. Insertion
  - c. deletion
  - d. duplication

APPENDIX I

STUDENT INTERVIEW QUESTIONS

### Student Interview Questions

1. What do you enjoy the most about biology?
2. How do you learn best in biology class?
3. Tell me in your own words what the purpose of the questions “What do I do? What do I see? What do I learn?” serve.
4. How well do these questions help you understand the lab? How well do these questions help you to remember the lab later on?
5. What type of lab do you prefer – structured labs or unstructured labs? Why?

APPENDIX J

JOURNAL PROMPTS

### Journal Prompts

1. How did students react to the lab?
2. If I could change how I presented the lab, what would I change
3. What part of the lab seemed to drag?
4. How well were the students acting independently (i.e. reading the labs, asking questions about procedures etc.)