

THE IMPACT OF INFUSING SCIENCE POETRY INTO THE BIOLOGY CURRICULUM

by

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July 2012

DEDICATION

This action research project is dedicated to the many students that I have taught and colleagues with whom I have worked who have embraced the ideals of cross curricular teaching and learning.

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ABSTRACT

As concrete as science is, it is a subject matter that is often difficult to understand because of the multifaceted concepts and technical vocabulary that is deeply rooted in the essence of the subject matter. Frequently, advanced science is studied in a closed environment where access to experiences is limited. This lack of accessibility forces a need for a more tangible means to help learners develop and anchor theoretical constructs. The use of poetry in the science classroom may be one such way to inform, engage and enhance students' understanding of abstract and complex scientific concepts. The descriptive techniques that are shared by science and poetry allow for creative, critical, and metaphoric thinking. Public high school honors biology students from Morristown High School were enrolled as participants in this study. This study was two-fold; Part I focused on determining the impact of infusing science poetry into the biology curriculum. Results were analyzed using a Two-Tailed Independent t-Test at $\alpha=.05$. Part II focused on the use of scientific poetic response as a summative assessment method to replace the traditional essay assessment. Results were assessed using a study-specific rubric and a Two-tailed Dependent t-Test for Paired Samples that compared each student's mean essay scores to their mean poetry scores at $\alpha=.05$. Also, Pearson's Correlation Coefficient (r) was utilized to establish any relationship between essays and poetic response assessments. This research demonstrated that there are some intersections and interactions across science and poetry that may assist students in comprehension of difficult abstract scientific material. Science poetry appears to be a tangible means to help learners develop and anchor theoretical constructs. The use of poetry in the biology classroom can inform, engage and enhance some students' understanding of abstract/complex scientific theories, concepts, and technical vocabulary. Offering learners an opportunity to reveal their understanding of complex biological concepts through scientific poetic response may just in fact be the much-needed scientific conceptual metacognitive summative assessment that many students and teachers have come to need. It is recommended that future research be conducted with a larger and more diverse population to further confirm affirmation of this study.

INTRODUCTION AND BACKGROUND

Project Background

Teaching Experience & Classroom Environment

I began my career teaching science and math education in a K-8 parochial school in Florham Park, New Jersey in 2000. Then after two years, I transitioned into a seventh grade life science position in the Morris School District. In 2003 I accepted a position as the Research Science Teacher in the Science Academy at Morristown High School. I currently teach three sections of Biology Honors, one section of Research Science Honors, and two sections of cross curricular science / humanities at the advanced levels. Biology Honors is one course that I teach that requires students to master and display an advanced level of understanding related to biological principles, theories, and concepts. Students enrolled in the course must pass a high-stakes Biology Content Exam that is administered by the state of New Jersey in May of each year. A passing score must be obtained in order to advance to the next science course and in future years graduate high school. Morristown High School operates a rotating block, which integrates full year and semester courses. Biology Honors is a full year course where students receive 3, 67- minute sessions of science exposure a week.

Student Demographics

Morristown High School is part of the Morris School District located in Morristown, New Jersey. The Morris School District draws from the communities of Morristown, Morris

Township, and Morris Plains and provides a supportive and challenging educational environment for a diverse student population of approximately 4,800 students. Within the district there is one pre-school, three primary schools (K-2), three intermediate schools (3-5), one multiage magnet school (K-5), one middle school (6-8), and one high school. Morristown is a diverse and long standing community that is located in the heart of Morris County, New Jersey.

Morristown High School has 1,491 students enrolled in grades 9-12 and is a microcosm of the greater New York metropolitan area, rich in diversity on various economic, racial, and cultural levels. Some students come from families that have been a part of the Morristown community for multiple generations, while others have only recently immigrated to the United States. Morristown High School offers a deep curriculum that is geared to prepare a student for post-secondary education, the military, trade school, or the workforce. Of the 1,491 students 59.8% of the population is White, 20.9% is Hispanic, 14.5% is African American, and 4.7% is Asian/Pacific Islanders. Over 19 different native languages are spoken within the student population. Of the 1,491 students who graduated in 2010, 93% of the graduating class was accepted to 4-year or 2-year colleges/universities. “The core value and primary purpose of Morristown High School, with its large and diverse population, is to foster a community in which learning is meaningful, challenging and lifelong, and where the expectations of growth, individual understanding, excellence and creativity exist for all students and staff in a dynamic and academic environment. This mission will be achieved through a research-based process of continuous and collaborative planning, implementation and evaluation” (Morristown High School, 2012).

Academic Overview

When students enter high school, not all of them are naturally excited to spend time in a science classroom or in the lab. I find that my passion and enthusiasm for the subject matter often ignites student interest in biology. I love teaching science; for me, it is not just a job, it is a vocation. The honors biology curriculum is an in-depth study of biology. It is a laboratory science course designed to acquaint students with the fundamental concepts of structure, function, characteristics and basic needs of organisms. Students need to demonstrate mastery of course proficiencies through successful completion of projects, activities, and performance based assessments. Areas of study include: biological principles, careers in biology, cells, genetics, evolution, taxonomy, ecology, microorganisms, plants, animals, and humans. The course provides a foundation for the topics covered on the New Jersey Biology Competency Exam and an introduction to select topics covered on the Biology E/M SAT II. However, many of students who enroll in the course lack the exposure or experience to understand complex and abstract biological concepts, and they are not prepared to master concepts as quickly as we must cover them at the honors level. On advanced topics such as cellular structures and processes (respiration, photosynthesis, ATP synthesis, cell cycle, protein synthesis, DNA replication, mitosis, and meiosis) I find that many students struggle because the subject matter is difficult to understand. The concepts are multifaceted and are often described by technical vocabulary that is abstract. Because of the limited accessibility of advanced microscopy, learning these fundamental ideas takes place in a closed environment and prevents learners from physically discovering or connecting with such advanced concepts. Furthermore, the complexity of the topics being explored often possess a challenge to me as the teacher to determine if a student truly understands the

material. Frequently, students can recall and recognize vocabulary and basic details, but I wonder how much of the information they really comprehend.

Over the past 11 years of my career, I have reflected upon student understanding. I have tried to find methods to assess conceptual mastery and knowledge transfer. Luckily, since 2006, I have been involved in a project that may be an innovative way of uncovering student understanding. This project has allowed me to explore the commonalities shared by both the domains of science and poetry. Science poetry (poetry that is driven by complex scientific subject matter) has the potential to engage students by making use of creative, critical, and metaphoric thinking.

Focus Question(s)

Primary Question:

Can scientific poetic response be used to demonstrate content mastery & understanding of advanced biological concepts?

Secondary Question:

Is scientific poetic response an alternative yet effective method of summative assessment?

Tertiary Question:

What is the impact of infusing science poetry into an honors biology curriculum?

CONCEPTUAL FRAMEWORK

As concrete as science is, it is a subject matter that is often difficult to understand because of the multifaceted concepts and technical vocabulary that are deeply rooted in so many of the abstract yet fundamental ideas that surround the essence of the subject matter. Frequently, advanced science is studied in a closed environment where access to experiences

is limited. When learners do not have an opportunity to physically discover or connect with advanced scientific concepts, the complexity of the topics being explored increases and true understanding cannot be guaranteed. This lack of accessibility forces a need for a more tangible means to be utilized in order to help learners develop and anchor theoretical constructs. The use of poetry in the science classroom may be one such way to inform, engage and enhance students' understanding of abstract and complex scientific theories, concepts, and technical vocabulary. The descriptive techniques that are shared by both the domains of science and poetry allow for creative, critical, and metaphoric thinking.

Science, similar to poetry, uses words as tools to further language specificity and precision, in order to allow others to better understand, experience, envision, and/or describe observations and phenomena. Both disciplines carefully use language. However, science specifically uses language to affirm the known and reduce uncertainty. It has been clearly established that poetry has been used in science classrooms for personal expression, memory aids, and demonstration of content mastery (Watts, 2001).

Science poetry is

any poem inspired and informed by scientific facts, phenomena, principles, theories, questions, observations, and experience if it includes all or most of the following elements: utilizes both quantitative and qualitative data within the poem, utilizes scientific facts, information, or experience to prompt or begin a poem, utilizes science, scientific theories, or phenomena as allusion, metaphor, or imagery in a poem, utilizes specific scientific and technical vocabulary in a poem, utilizes science as the subject or theme of a poem. (Gorrell & Colfax, 2012, p.19)

Science poetry for some is part of an imaginative practice that formulates scientific explanations in order to broaden the depth of intellectual understanding of the known, unknown, and unimaginable. Poetry can serve to provide the conceptual framework for abstract scientific explanations. The language used to express such meaningful science interweaves literary leaps and metaphors that enhance complex scientific understandings (Hoffmann, 2003). Furthermore, according to Frazier and Murray (2009), integrating poetry into science is a pedagogical approach that re-introduces the language of philosophy that was previously embraced as in the Renaissance and Enlightenment Eras when philosophical explanations preceded empirical ones and educational practices fostered learning about the natural world, which in turn generated enthusiasm for curiosity.

Over the last several decades, it has come to the attention of educators that students learn best when they develop personal understandings based in meaningful educational experiences as opposed to when they are simply a receiver of information. In a 2001 study conducted by Alber and Patton, colleagues and instructors at the Darlington School, found that writing science specific poetry in AP chemistry classes, assisted students in finding ways to connect chemistry to other disciplines. Specifically, the use of poetry seemed to engage open-minded students who had a love of science and a general respect for poetry to write and appreciate poetry in a new light. Furthermore, students developed a deeper appreciation for the creative side of science and for some, poetic expression increased excitement, engagement, and productivity in a new and different manner in the science classroom.

Young, Connor-Greene, Woldvogel and Paul in 2003 created *Poetry Across the Curriculum* (PAC) and ran a widespread research study that included 24 faculty members and students from five different post-secondary collegiate institutions. The study enrolled

professors and students from various departments and asked them to compose poetry in response to course readings and other content related prompts. After extensive analysis of the data received (faculty surveys, reflections written by students, textual examination of student poems, and case studies of classes from four different disciplines), it was affirmed that when students authored their own poems they were able to attach personal meaning to the content which in turn, provided students with the chance to take ownership of their experiences. The PAC program which was initially modeled after the *Writing Across the Curriculum* (WAC) concept, was an innovative approach to get students to creatively express the knowledge they obtained in their content area in science and build more significant connections between disciplines outside of science.

Watts (2001) explored the many relationships educators have made between science and poetry. He determined that there could be a deep connection between the two disciplines and that “the teacher presenting poetry in class, specifically his or her own favorite verses, operates as an eloquent role-model for learners and can act to restore life to science’s otherwise fading image.” Poetry not only gives a voice to the poet, but also gives a voice to science when the meaning is deeper than the eye can see.

The emergence of innovative practices in science poetry like those embraced by Alber and Patton, Young, Connor-Greene, Woldvogel and Paul, as well as Watts has led education professionals into conversations about re-thinking assessment practices in order to determine subject specific understandings. Doing so has forced a change in traditional assessment and instructional delivery practices (Goubeaud, 2010). For decades, the thought was that assessment should take place after students have established content mastery and should be in the form of forced choice and short answer responses in order to provide

evidence of scientific understanding. Now, however, it has been widely accepted to offer students an open-ended assessment where learners are better able to demonstrate content mastery authentically by paralleling real life situations. When assessments are open-ended, they can function as measurement tools beyond that of pure evaluation. Open-ended assessments in science are seemingly in alignment with state and national standards and ultimately correlate to practical content-based understandings (Goubeaud, 2010).

According to a 1999 U.S. Department of Education study that assessed the grading practices of over 819 post-secondary science faculty, it was determined that there is validity in scientific writing assessments that measure the process and products of scientific knowledge. Essay exams, research and term papers, and multiple drafts of written work collectively allow students to broaden their thinking, enhance the learning process, and reveal complex learning outcomes (Goubeaud, 2010). Conversely, multiple choice and short answer exams often measure cognitive thought that is at the lower end of Bloom's Taxonomy and rarely allow for flexibility in response. Biology courses in particular, offer a more diverse array of assessments to nurture and evaluate science learning as compared to their physics and chemistry counterparts because of the nature of the subject matter.

The committee on Classroom Assessment and the National Science Education Standards (2001) has shared that the goal of school science is to continue to move away from traditional assessment practices and engage in assessment that allows students to make connections between their understandings of the natural world and the current knowledge and theories accepted by the greater scientific community. In doing so, the committee argue that there is a need for strengthening assessment in the science classroom so that students learn from assessments that they are engaged in. Such assessments that embrace the complex

nature of science and display interconnectedness with other bodies of knowledge can actually serve to expand a child's learning. Offering learners an opportunity to reveal their understanding and mastery of complex biological concepts through scientific poetic response (the creation of a science poem) may just in fact be the much-needed scientific conceptual metacognitive summative assessment that many students and teachers need. The committee on Classroom Assessment and the National Science Education Standards (2001), has gone on to state that "summative assessment... is intended to capture what a student has learned... and although we often think of summative assessment as traditional objective tests, this need not be the case." Scientific Poetic Response (the creation of a science poem) is a different kind of assessment that may actually assist students in becoming stronger at inquiring about the world of science around them. It could serve to support acquisition by having students obtain information about content areas while they are actually engaged in making connections beyond the obvious and expressing such understandings through similes, metaphors, and analogies. By offering students alternative assessments like the scientific poetic response (The committee on Classroom Assessment and the National Science Education Standards (2001)), they are getting an opportunity to make sense of what they are learning, integrating data in context, and articulating their understandings in a new and innovative way. The National Science Standards were established in order to support student learning of science information on a level greater than merely recall and recognition of science facts and skills. The committee on Classroom Assessment and the National Science Education Standards (2001) looks to Stiggins, a science education scholar, who acknowledges that in order to widen our understanding and array of science assessments, it is important that assessments focus on student mastery of content that embraces knowledge and

understanding, utilizes knowledge to reason and solve problems, develops performance skills, fosters a student's ability to create products that meet certain standards of quality, and increases the development of important dispositions.

METHODOLOGY

The purpose of this study was twofold; Part I was to determine if the infusion of science poetry during instruction produced increased quiz scores on science content. More specifically, the science quiz scores from students who experienced the poetry infusion (school year 2011-2012) were compared to the science quiz scores from students who did not experience the poetry infusion (school year 2010-2011). Part II focused on the use of scientific poetic response as an alternative summative assessment method to replace the traditional essay assessment. Prior to beginning the investigation, 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.

Currently the Principal Investigator teaches three sections of Biology Honors. Fifty-nine student participants from these classes were invited to enroll in this study; however, 58 student participants completed part I of the study and 51 student participants completed part II of the study. The composition of the biology classes is reflective of students in grades 9-10 and range in age from 14-16 years old. This study population reflects a microcosm of the greater New York metropolitan area and is composed of students that come from diverse families in terms of racial, cultural and socio-economic levels. Some students have families that been a part of the greater Morristown community for multiple generations while others

have only recently immigrated to the United States. Of the 51 student participants 69% of the population is White, 8% is Hispanic, 7% is African American, 12% is Asian/Pacific Islanders and 3% is European and thirty of the total student participants were females. Of the 51 students who enrolled in the study, 37% were accepted into the Science Academy, a small learning community housed within Morristown High School that identifies students as having advanced to advanced proficient competency in science and mathematics as an eighth grader.

In Part I of the study, where the Principal Investigator sought to determine if the infusion of science poetry during instruction produces increased quiz scores on science content from 2010-2011 school year to 2011-2012 school year, content specific science poems written by the Principal Investigator, distinguished poets, renowned scientists, prominent science poets and amateur science poets were distributed and dissected by students and the Principal Investigator throughout the teaching and learning process during the school year. The curricular content areas that had poetry infused during this part of the study were: biochemistry: elements & water, ecology: biogeochemical cycles, biodiversity, & renewable resources, levels of organization: organs, tissues, cells, organelles, & cellular processes, Genetics: transcription, translation, DNA synthesis, mitosis, meiosis, evolution, plants: flowers, transpiration & photosynthesis, animals: interactions with one another & specific organisms. There were 67 students enrolled in the 2010-2011 school year and 58 students enrolled in the 2011-2012 school year. Participants enrolled in the 2011-2012 school year were given the exact same quizzes as in 2010-2011 school year. However, the quiz scores from the 2010-2011 school year were reflective of student understandings and knowledge gained in the biology content area after being taught the curricular topics *without* the infusion

of science poetry. The independent variable being tested was the infusion of content specific science poetry into the biology curriculum and the dependent variable was the science test scores.

In order to establish methods of quality control and minimize introducing additional external variables, the following variables were controlled:

- The biology honors curriculum that was taught in the 2010-2011 school year was the exact same curriculum in the 2011-2012 school year.
- The instructor during the 2010-2011 school year was the exact same instructor in the 2011-2012 school year.
- The quiz review sheets that were used in the 2010-2011 school year were the exact same as in the 2011-2012 school year.
- The quizzes that were administered during the 2010-2011 school year were the exact same quizzes administered in the 2011-2012 school year.
- The grader of the quizzes that were administered during the 2010-2011 school year was the exact same grader in the 2011-2012 school year.
- The instructional methods employed by the instructor during the 2010-2011 school year were the exact same methods in the 2011/2012 school year (with the exception of poetry infusion).

A summary of the treatment timeline is located in Table 1. Results from Part I of the study were analyzed using a Two-Tailed Independent t-Test at $\alpha=.05$.

Part II of the study focused on the use of scientific poetic response as an alternative summative assessment method to compliment or perhaps even replace the traditional essay assessment. The content areas that were examined during Part II of this study were advanced

topics in honors biology such as cellular structures and processes (respiration, photosynthesis, ATP synthesis, cell cycle, DNA replication, mitosis, and meiosis, protein synthesis). Many of these topics were introduced to the students for the first time at such a deep level. These concepts can be very difficult to understand. They are multifaceted and are often described by technical vocabulary that is abstract to the learner. Because of the limited accessibility of advanced microscopy, learning the fundamental ideas of such concepts takes place in a closed environment and prevents learners from physically discovering or connecting with such advanced concepts.

Fifty one students were enrolled as participants and were first introduced to essay writing techniques in order to learn how to write and prepare a solid essay in biology. Participants were then introduced to descriptive language techniques (such as metaphor, simile, and analogy) in order to construct a scientific poetic response (science poem) in biology. As advanced abstract biological concepts were revealed throughout the course, students examined exemplar essays and science poems that incorporated such techniques to assist in expanding a student's foundational knowledge on select biological topics. At the conclusion of each conceptual unit, students were asked to display their understanding of selected biological concepts in the form of a scientific poetic response (science poem) and a traditional essay response. Four different scientific poetic response (science poem) and essay response prompts were administered (Appendix E). The first two prompts were untimed and allowed students to utilize their notes and/or textbook while writing their scientific poetic response (science poem) and essay responses. The latter two prompts did not allow students to utilize their notes and/or textbook while writing their scientific poetic response (science poem) and essay responses. The latter two prompts were timed. Students were limited to 50

in-class minutes. A Study Specific Holistic Science Writing Assessment Rubric (Appendix D) that focused on scientific accuracy, language techniques, illustration of scientific concepts, and indicates mastery of skills was used to assess student content mastery and understanding. In order to establish methods of quality control and minimize introducing additional external variables, the following variables were controlled:

- Participants were given instruction on how to construct a solid traditional essay response and how to construct a scientific poetic response (science poem).
- Participants were given exemplar essay responses and scientific poetic responses (science poem) to read, review, and analyze prior to being assigned.
- One of the two scorers of the essay response and scientific poetic response (science poem) was consistently the same.
- One Certified Science and/or one English Secondary Education scorers were used to grade the essay responses and scientific poetic responses (science poems) and were trained prior to the start of the study.
- The Study Specific Holistic Science Writing Assessment Rubric was used to assess both the traditional essay response and the scientific poetic response (science poem).

A summary of the treatment timeline is located in Table 2. Results were analyzed using a Two-tailed Dependent t-Test for Paired Samples that compared each student's mean essay scores to their mean poetry scores at $\alpha=.05$. Also, Pearson's Correlation Coefficient (r) was utilized to establish any relationship between essays and poetic response assessments.

Table 1
Treatment Implementation Timeline Part I

Unit of Study	Concepts Covered	Time Frame
Infusion of Science Poetry	Biochemistry: elements & water Ecology: biogeochemical cycles, biodiversity, & renewable resources Levels of organization: organs, tissues, cells, organelles, & cellular processes: photosynthesis/respiration Genetics: transcription, translation, DNA synthesis, mitosis, meiosis, protein synthesis	September 2011 – March 2012
Administration of content specific Quizzes	Biochemistry: elements & water Ecology: biogeochemical cycles, biodiversity, & renewable resources Levels of organization: organs, tissues, cells, organelles, & cellular processes: photosynthesis/respiration Genetics: transcription, translation, DNA synthesis, mitosis, meiosis, protein synthesis	September 2011 – March 2012
Analysis of Quiz Scores	Results from part I of the study were analyzed using a Two-Tailed Independent t-Test ($\alpha=.05$)	April 2012

Table 2
Treatment Implementation Timeline Part II

Unit of Study	Concepts Covered	Time Frame
Principal Investigator explained research investigation to parents and students	Research participant letter distributed to students and parents In-class discussion with students Back to school night discussion with parents (See Appendix 1)	September 2011
Principal Investigator distributed and explained the Science Writing Pre-student survey	Science Writing Pre-student survey (See Appendix 5)	October 2011
Principal Investigator taught <i>science essay writing techniques</i> and provided an exemplar essay in order for students to learn how to write and prepare a solid essay in biology.	Mastering themes and overall ideas of biology concepts. Recalling broad information in an organized way. (See Appendix 2)	October 2011 – November 2011
Principal Investigator taught <i>descriptive language techniques</i> and provided an exemplar science poem in order to learn how to construct a scientific poetic response (science poem) in biology.	Generating Metaphors, similes, and analogies of abstract biology concepts. (See Appendix 3)	October 2011 – November 2011
Principal Investigator reviewed with participants Study Specific Holistic Science Writing Assessment Rubric.	Participants reviewed <i>Study Specific Holistic Science Writing Assessment Rubric</i> that focused on scientific accuracy, language techniques, illustration of scientific concepts, and indicates mastery of skills (See Appendix 4)	October 2011 – November 2011
Principal Investigator explained research investigation launch to parents and students	Research participant letter II distributed to students and parents In-class discussion with students (See Appendix 17)	November 2011
Taught advanced topics in honors biology	Cellular structures and processes: (respiration, photosynthesis, ATP synthesis, cell cycle, DNA replication, mitosis, and meiosis, protein synthesis)	December 2011 – March 2012
Principal Investigator distributed and explains the Science Writing Post-student survey	Science Writing Post-student survey (See Appendix 5)	March 2012
Administration of scientific poetic responses and traditional essay responses	Participants displayed their understanding of selected biological concepts in the form of a scientific poetic response and traditional essay response	December 2011 – March 2012
Analysis of <i>Holistic Science Writing Assessment Rubric</i> Scores	Results analyzed using a Two-tailed Dependent t-Test for Paired Samples to compare mean essay scores to mean poetry scores ($\alpha=.05$). Pearson's Correlation Coefficient (r) was utilized to establish any relationship between essays and poetic response assessments.	April 2012

DATA AND ANALYSIS

In order to evaluate the effectiveness of scientific poetic response and to answer the focus question and sub-questions, the following data was gathered:

- 10 Quiz scores on science content from 2010-2011 school year for each participant enrolled
- 10 Quiz scores on science content from 2011-2012 school year for each participant enrolled
- Study Specific Science Writing Pre- survey from each participant enrolled
- Study Specific Science Writing Post- survey from each participant enrolled
- Holistic Science Writing Assessment Rubric Scores for scientific poetic response from each participant enrolled
- Holistic Science Writing Assessment Rubric Scores for traditional essay response
- Principal Investigator reflective journaling
- Student Interviews from 14% of the participants enrolled
- Student profiles for the 2011-2012 school year to get basic demographic data on each participants enrolled

Table 3
Data Triangulation Matrix

Focus Questions	Data Source 1	Data Source 2	Data Source 3
Primary Question: Can scientific poetic response be used to demonstrate content mastery & understanding of advanced biological concepts?	Study Specific Science Writing Pre-survey from each participant enrolled and Study Specific Science Writing Post- survey from each participant enrolled	Holistic Science Writing Assessment Rubric Scores for scientific poetic response & traditional essay response from each participant enrolled	Reflective Journal
Secondary Question: Is scientific poetic response an alternative yet effective method of summative assessment?	Study Specific Science Writing Pre-survey from each participant enrolled and Study Specific Science Writing Post- survey from each participant enrolled (Appendices 5 & 6)	Holistic Science Writing Assessment Rubric Scores for scientific poetic response & traditional essay response from each participant enrolled	Reflective Journal
Tertiary Question: What is the impact of infusing science poetry into an honors biology curriculum?	Quiz scores on science content from 2010-2011 school year & 2011-2012 school year	Quiz scores on science content from 2011-2012 school year & 2011-2012 school year from each participant enrolled	Reflective Journal Student Interviews

The analysis of the data uses a combination of descriptive and inferential statistics in order to establish statistical triangulation. Part I of the study, sought to determine if the infusion of science poetry during instruction produced increased quiz scores on science content from the 2010-2011 school year to the 2011-2012 school year. Results from Part I of the study were analyzed using a Two-Tailed Independent t-Test using the established educational research α -value of .05.

It was determined that eight of the ten quizzes that were administered yielded results where the mean quiz scores from the 2010-2011 school year were actually higher than that of the 2011-2012 school year where science poetry was integrated (Figure 1). Five out of the ten quizzes administered in the 2010-2011 school year yielded statistically significant higher results than those same quizzes when administered in 2011-2012, where poetry was infused. The scores from the pH/water quiz, carbohydrate quiz, ecology quiz 1, ecology quiz 2, & cell cycle quiz reflect such statistical significance (Figures 1, 2, & Appendix S).

	pH/water quiz Scores			Carbohydrate Quiz Scores			Ecology Quiz 1 Scores			Ecology Quiz 2 Scores			Microscope Quiz Scores		
	Mean	Std. Dev.	Count	Mean	Std. Dev.	Count	Mean	Std. Dev.	Count	Mean	Std. Dev.	Count	Mean	Std. Dev.	Count
2010-2011	81.70	13.04	67	81.10	11.70	67	83.80	9.18	67	93.65	6.48	67	76.64	15.2300	67
2011-2012	62.90	17.90	58	73.80	21.90	58	79.30	14.30	58	90.86	8.43	58	79.31	13.4800	58
	Organelle Quiz Scores			Cell Cycle Quiz Scores			Genetics Quiz Scores			Meiosis Quiz Scores			Protein Synthesis Quiz Scores		
	Mean	Std. Dev.	Count	Mean	Std. Dev.	Count	Mean	Std. Dev.	Count	Mean	Std. Dev.	Count	Mean	Std. Dev.	Count
2010-2011	88.16	12.84	67	87.90	11.60	67	81.00	15.20	67	87.30	10.00	67	87.40	7.91	67
2011-2012	88.01	12.10	58	79.80	17.90	58	76.50	16.10	58	84.90	13.10	58	89.39	9.79	58

Figure 1. Part 1: Quiz Score Comparisons.

	pH/water quiz					Carbohydrate Quiz					Ecology Quiz 1					Ecology Quiz 2					Microscope Quiz				
	Mean	Std. Dev.	t-ratio	DF	prob > t ; p =	Mean	Std. Dev.	t-ratio	DF	prob > t ; p =	Mean	Std. Dev.	t-ratio	DF	prob > t ; p =	Mean	Std. Dev.	t-ratio	DF	prob > t ; p =	Mean	Std. Dev.	t-ratio	DF	prob > t ; p =
2010-2011	81.70	13.04	-6.63	102.70	0.0001	81.10	11.70	-2.26	84.10	0.03	83.80	9.18	-2.05	94.50	0.04	93.65	6.48	-2.05	106.00	0.0427	76.64	15.2300	1.0380	2.0380	3.0380
2011-2012	62.90	17.90				73.80	21.90				79.30	14.30				90.86	8.43				79.31	13.4800			
	Organelle Quiz					Cell Cycle Quiz					Genetics Quiz					Meiosis Quiz					Protein Synthesis Quiz				
	Mean	Std. Dev.	t-ratio	DF	prob > t ; p =	Mean	Std. Dev.	t-ratio	DF	prob > t ; p =	Mean	Std. Dev.	t-ratio	DF	prob > t ; p =	Mean	Std. Dev.	t-ratio	DF	prob > t ; p =	Mean	Std. Dev.	t-ratio	DF	prob > t ; p =
2010-2011	88.16	12.84	-0.0600	122.00	0.9477	87.90	11.60	-2.95	95.57	0.0039	81.00	15.20	-1.577	118.20	0.1173	87.30	10.00	-1.12	105.80	0.2643	87.40	7.91	1.23	109.40	0.2180
2011-2012	88.01	12.10				79.80	17.90				76.50	16.10				84.90	13.10				89.39	9.79			

Figure 2. Part 1: Summary of Independent T-Test.

It can be concluded then that the two groups are comparable in terms of demographics. However, the collective differences may be attributed to the fact that there were 58 student participants in 2011-2012 school year and there were 67 student participants in the 2010-2011 student participant population. Additionally, although it cannot be confirmed, I surmise that the overall academic aptitude of the 2010-2011 student participants may have been higher than the 2011-2012 student participants thus driving down the means of the quiz scores. Academic aptitude is often measured through test and quiz assessments. If a student had a lower academic aptitude, it is possible that it could potentially drive down their assessment scores. If I was permitted to have access to such academic aptitude data, I would have run an ANCOVA (Analysis of Covariance) for the purpose of comparing the science quiz scores from both years, while statistically adjusting for “IQ”.

Part II of the study, focused on the use of scientific poetic response as a summative assessment method to replace the traditional essay assessment. Results from Part II of the study were analyzed using a Two-tailed Dependent t-Test for Paired Samples to compare

each student's collective essay scores to their collective poetry scores using the established educational research α -value of .05 (Goubeaud, 2009). Also, Pearson's Correlation Coefficient (r) was utilized to establish any relationship between essays and poetic response assessments.

There were 51 student participants who completed part II of the study; 47 of which completed a pre and post study survey. Prior to the study, students were asked if they liked to write poetry. Of the student participants who responded 57% responded that they did. These indications lead the Principal Investigator to believe that the study population would be somewhat responsive to participating in the research. It was determined that two of the four collective mean scientific poetic response (science poem) assessment scores were higher than the traditional 5-paragraph essay response assessment scores. Although none of these scores were statistically significant (Figure 3 & Appendix T), the data revealed that the scientific poetic response may in fact be a valuable assessment instrument to consider in addition to the traditional 5-paragraph essay response assessment.

	Cell				DNA			
	Mean	t-ratio	DF	prob > t ; p =	Mean	t-ratio	DF	prob > t ; p =
Essay	3.71	-1.1500	49	0.2554	3.64	-1.1060	50	0.2737
Poem	3.86				3.74			
	Photosynthesis / Respiration				Protein Synthesis			
	Mean	t-ratio	DF	prob > t ; p =	Mean	t-ratio	DF	prob > t ; p =
Essay	3.86	-1.6070	49	0.1144	3.94	0.330	50	0.7425
Poem	3.62				3.90			

Figure 3. Part 2: Summary Dependent T-Test Results, (N=51).

Participants generated poems and essays that contained evidence of meaningful fusion of science and written expression by: employing techniques of William's Taxonomy

of Creative Thought (fluency, flexibility, originality, elaboration, risk taking, complexity, curiosity, & imagination), exhibiting scientific knowledge by employing and defining specific and appropriate scientific vocabulary terms, explaining scientific concepts using a combination of metaphors, similes, or analogies, demonstrating scientific knowledge by applying and analyzing, concepts, using examples in order to show the scientific process, integrating qualitative and quantitative data, organizing thoughts in respect to the science concept being assessed, and making related connections to extend the science concept.

After analyzing the results on a series of contingency tables (a statistical methodology that allows for 2 or more continuous variables to be analyzed in order to see if there is a relationship that exists between the variables), it was determined that specifically on the DNA poem, 84.48% of the participants who earned a 4 on the essay earned at least a 4 or better on the corresponding poem.

Furthermore, after running a series of multivariate correlations it was determined that collectively, as essay scores go up, so do their corresponding poem scores. As seen in Figures 4, 5, 6, & Appendix U, the strongest correlation found was between the DNA poem and the DNA essay; this correlation was also deemed statistically significant. There was a slight correlation between the Protein Synthesis poem and Protein Synthesis essay as well as between the Cell poem and Cell essay. There was however, a limited correlation between the Photosynthesis / Respiration poem and Photosynthesis / Respiration essay.

	Protein Syn. Poem Mean	Protein Syn. Essay Mean	DNA Poem Mean	DNA Essay Mean	Photo/res Poem Mean	Photo/res Essay Mean	Cell Poem Mean	Cell Essay Mean
Protein Syn. Poem Mean	1.0000	0.5611	0.3342	0.4810	0.2828	0.1158	0.3839	0.3785
Protein Syn. Essay Mean	0.5611	1.0000	0.5508	0.6729	0.3427	0.2676	0.4059	0.5546
DNA Poem Mean	0.3342	0.5508	1.0000	0.5803	0.3068	0.3234	0.4288	0.4283
DNA Essay Mean	0.4810	0.6729	0.5803	1.0000	0.3240	0.2304	0.3765	0.4552
Photo/res Poem Mean	0.2828	0.3427	0.3068	0.3240	1.0000	0.1143	0.2427	0.1226
Photo/res Essay Mean	0.1158	0.2676	0.3234	0.2304	0.1143	1.0000	0.3429	0.2302
Cell Poem Mean	0.3839	0.4059	0.4288	0.3765	0.2427	0.3429	1.0000	0.3663
Cell Essay Mean	0.3785	0.5546	0.4283	0.4552	0.1226	0.2302	0.3663	1.0000

Figure 4. Part 2: Data and Analysis Multivariate Correlations, (N=51).

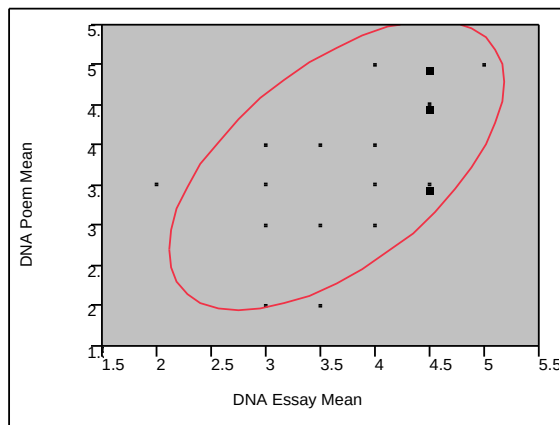


Figure 5. Part 2: Data and Analysis Fit Y by X Group: Bivariate Fit of DNA Poem Mean vs. DNA Essay Mean, (N=51).



Variable	Mean	Std Dev	Correlation	Signif. Prob	“N” Number
DNA Essay Mean	3.647059	0.62685	0.580313	<.0001*	51
DNA Poem Mean	3.745098	0.737377			

Figure 6. Part 2: Data and Analysis Fit Y by X Group: Bivariate Fit of DNA Poem Mean vs. DNA Essay Mean Correlation, (N=51).

Poems and essays that earned scores of 5/5 on the Study Specific Holistic Writing Assessment Rubric, reflected a mastery level of command and were deemed as outstanding science writing by the scorers. For example, one such poem on the topic of protein synthesis, authored by Uky contained a stanza that stated: “Pre-mRNA may not always be right, the introns are cut out; the exons are kept tight. And like a final draft, the mRNA is good; ready for translation, just like it should.” This particular stanza exemplifies the deep level of understanding that Uky had about the essential process of cutting out non-coding regions of RNA prior to their leaving the nucleus. Not only did Uky display understanding by directly stating the basic steps of the process, she also integrated a clear and accurate analogy. Furthermore she employed specific and appropriate scientific vocabulary terms.

Another poem authored by Aby; contained a variety of analogies to extend his understanding of the science topic Photosynthesis and Respiration. Aby compared the electron carrier molecule (NAD⁺) to the movement of a football in a reverse play. He went on to equate a chloroplast to a solar panel; since both are meant to absorb the sun’s energy. In making such connections Aby was able to extend the science concept and display a level of mastery relative to the concept being assessed.

An exemplar poem written by Mhy, met all of the essential criteria for receiving an outstanding science writing score. Her poem broke down the abstractness of the topic of

DNA structure and replication and provided the reader with concrete metaphors and analogies.

I have brown hair and hazel eyes

But I do have one question

Why?

Watson and Crick, just two scientists

Made an incredible development

The Double Helix

DNA Structure

One pair base, two pair bases, three!

Just like a spiral staircase

One step, two steps, and three!

Made up of two different groups

Phosphate and deoxyribose

Come in a pack

But not only known for that

The backbone is there, set in stone

Although that is not all

We can't forget the bases after all

There's pyrimidines and purines

One ring and two

Paired only as AT or GC

Who knew?

But there is also a code

Hidden perpendicular to the backbone

It holds the information we need

All about our heredity

But there is only one way

They can all stay

BONDS, BONDS, BONDS!

Hydrogen weak,

Covalent strong

All with one purpose, they won't get it wrong

Just like a glue

They hold DNA together

Do you get the clue?

But just like you and me

DNA doesn't want to be alone

It needs a friend, how about a clone?

A four step process

Let's make it quick

Start with helicase, just unzip

The DNA splits

So if you put them together they would still fit

Next up is polymerase

Takes the sub particle of DNA called nucleotides

From the nucleoplasm, its home

Like taking a cub from all it's known

But you know, it does not stop there

Now replication has turned a new direction, but where?

With one leading, and one lagging

Ligase it is called

Joins the two segments together

So there is no winner in this race at all

One more step for this process to face

Called endonuclease

It checks everything just been done

And fixes the mistakes until there are none

Just like a proof read machine

Corrects them for you and me

Now replication is done

There are one billion more pairs then, which we started from

That is all you must see

All that makes up we

Our size

Out height

Our looks

Our weight

Can't be done if DNA doesn't replicate

Another outstanding poem written by student Asy, on the topic of Protein Synthesis revealed her employment techniques of William's Taxonomy of Creative Thought (fluency, flexibility, originality, elaboration, risk taking, complexity, curiosity, & imagination) while at the same time balancing the scientific and poetic components.

The structure of DNA did not actually explain how a gene worked

DNA and its spiral structure was simply incomplete

It was the discovery of the RNA

RNA was the program to a robot as it was involved in putting the genetic code into action

DNA contains instructions that the cell follows to build proteins

The first step through is to make a photocopy of a part of a DNA sequence into RNA

RNA uses the instructions to direct the production of proteins

Which helps paint the portrait of an organism's characteristic

DNA and RNA are quite different, although both are made up of a 5 carbon sugar, phosphate group, nitrogenous base

RNA sugar is single ribose and DNA sugar is deoxyribose, since DNA lacks the {-} pole of the Mickey Mouse shaped water molecule

RNA is single-stranded, like a curly strand of hair

Finally, in place of thymine, RNA contains uracil

DNA is like a master plan

A master plan that contains all of the instructions to a construction site

But, since builders never use the original plan, in fear that someone might spill their water or step on it with their muddy boots,

RNA, or the blueprint, is the disposable copy of the master plan

DNA stays safely in the cell

While RNA travels to the ribosome in the cytoplasm

RNA is a disposable segment of DNA

As a blueprint is disposable copy of the master plan

RNA has many functions

But mostly are employed for one kind of job; protein synthesis

RNA controls the assembly of amino acids into proteins

Like organelles in a cell, RNA molecules are specialized in different roles

There's messenger RNA, transfer RNA, and ribosomal RNA

Messenger RNA carries instructions for protein synthesis from the nucleus to a ribosome

Transfer mRNA carries amino acids to the ribosome and links itself to the coded mRNA message & is like an adaptor that enable the ribosome to “read”

Ribosomal RNA makes up two subunits of a ribosome or the ceiling floor of a construction site

RNA synthesis occurs in the first step of polypeptide synthesis known as transcription

Segments of DNA are used as templates to produce complementary or matching puzzle piece RNA molecules

The back sequences of the transcribed RNA is the compliment to the 4 nucleotide beaded nucleic acid necklace; DNA

Transcription requires the enzyme RNA polymerase like DNA, RNA polymerase binds to the DNA and unzips a portion of the spiral staircase

It then uses one strand of DNA as a template from which a complementary blueprint is created

DNA polymerase doesn't bind to DNA anywhere the enzyme binds to a promoter region

A promoter region is like traffic light that tells a car when to go

Promoters are signals that show RNA polymerase exactly where to begin making RNA

Finally, RNA is sent to the teacher, who edits and corrects the strand
introns, or unnecessary information, are discarded exons are spliced together
And a cap and tail, like the title and conclusion of the essay are added, so that the
mRNA is complete

The final step to the polypeptide synthesis is a matter of reading the genetic code, aka
translation

mRNA's four bases (A, C, G, & U) form a language of just four words

The genetic code is read three "letters" at a time

Each word or codon is three bases long and correspond to an amino acid

Codons can also serve as punctuation marks in English

Just like punctuation tells us when to pause, start, and stop, a genetic code also
contains punctuation marks, known as start and stop codons

AUA for example is the start codon that will allow for mRNA to be read until it
reaches one of the three different stop codons

Ribosomes use the sequence of codons in mRNA to assemble amino acids into a
polypeptide chain

Translation is a process that decodes a mRNA message into a protein

Translation occurs in the construction site or ribosome

After, mRNA leaves the nucleus and enters the ribosome

First, ribosome shakes hands with mRNA

It lets mRNA exercise on the tread mill; a conveyor belt so each codon can pass through the ribosome

tRNA brings the proper amino acid into the ribosome

Each tRNA anticodon is complementary to an mRNA codon that allows for an amino acid

Like an assembly-line employee, the ribosome attaches one part to another to help form a peptide bond between amino acids

At the same time, the Elmers glue dries between that tRNA molecule and its amino acid

The assembly-line worker then moves to the next codon

The protein chain grows like a necklace in the making until the ribosome reaches one of 3 different stop codons

This completes translation

The three RNA specialists all contribute in the second step of protein synthesis

DNA, RNA, and proteins are all involved in putting genetic information into action in living cells

They all help in depicting, illustrating, and designing an organism's characteristics

These exemplarily lines and poems along with the collective results gathered in Part II of the study further reveal that the scientific poetic response (science poem) may in fact be a valuable assessment instrument to consider in addition to the traditional five-paragraph essay response assessment in biology.

After the study, students were asked a series of questions comparing the two assessment types using the Science Writing Post-study survey. Prior to completing the survey the following terms were clarified and explained to the students: confusing, distracting, chunking, and visualizing. One question in particular asked student participants if they felt that writing the scientific poetic response provided them with the opportunity to chunk their understanding of selected biological concepts; 55% of the 47 participants who responded claimed that this was the case. When asked a similar question, if they felt that the traditional 5 paragraph essay response provided them with the opportunity to chunk their understanding of selected biological concepts; 68% of the 47 participants who responded claimed that essay writing also provided them with the opportunity to chunk their understandings (Appendix V). Additionally, student participants were asked if they felt that writing the scientific poetic response provided them with the opportunity to visualize the biological concepts; 70% of the 47 participants who responded claimed that this was the case. When asked a similar question, if they felt that the traditional 5 paragraph essay response provided them with the opportunity to visualize the biological concepts; only 57% of the 47 participants who responded claimed that this was the case (Appendix V). Thus indicating that 13% more of the student participants felt that the scientific poetic response was a means by which to visualize the biological concepts. Ten more females as compared to males claimed this to be the case.

At the completion of the study, students were also asked if they were willing to be interviewed and answer a few questions regarding the use of poetry and essay writing in science class. Seven out of 51 students enrolled who participated in the study were interviewed, it should be noted that the majority of the students who were willing to be interviewed seemed to enjoy the process of writing poetry and writing essays in biology class. These same students also seemed to excel at the science poetry writing process. Only three of the students interviewed had a negative or indifferent view about writing science poetry in biology class. There were students from all three class sections represented; three of the students were female and the other four were male. During the interviews students described a favorable view of writing poetry as an alternative to writing an essay. One student, Chy claimed, “I liked using poetry in our science class. In my opinion it gave me a way to finalize my understanding of knowledge that we recently learned.” He went on to say that he found that the poetry was very helpful and he often went back to the poem to help him remember concepts. Another student, Jty claimed, “Using poetry in class is very helpful when it comes to visualizing the lessons. The analogies that we use make it easier to understand functions of some of the things we've learned.” Her testimonial was reinforced by the collective participant response data gathered; 70% of the students enrolled felt that science poetry provided a visualization of the concept being explored. Aly, another student, stated,

In an attempt to reinforce our understanding of specific concepts in Biology, we wrote scientific poems. I thought that writing poetry in science was very helpful to help describe distinct concepts in ways that I was able to relate to. I think that some of the ideas in Biology can be hard to grasp, and with the integration of poetry into

our lessons, I am able to gain a better understanding of scientific information. The poems did help me better visualize the science concepts by including comparisons that I could relate to. This helped put these concepts into a better perspective. By arranging poetic ideas into stanzas, I was able to organize chapters in Biology in a way that concepts related and flowed together. This way helpful for me, helping to link the broader ideas covered in the chapter together, formulating a more in-depth overall understanding.

Aly and Jty were also able to compare concepts in biology with what they referred to as real life things.

When interviewing students and asking them about their feelings towards writing essays in science class, some students shared that they were not very fond of writing essays, but realize why they must write them. Other students claimed that they were indifferent about the process of writing an essay or didn't mind it. Khy commented, "I think essay writing makes it hard to prove my understanding of the concept. I focus too much on sentence structure and variation then on explaining the material. Also, it is hard to include everything we learned when you have to elaborate and explain everything." Chy went on to share, "When I write essays I find myself just writing down as much as I can remember from past lessons and I do not feel as though I really know the material enough while and after writing the essays themselves". However, other students commented that because the essay was focused and well organized they did not mind writing the essay, it just did not allow their creativity to be expressed in the same way that a poem could. Student Bcy shared,

I did feel that the essay helped break down the concepts into chunks. Because essays are set up in paragraphs, it really helped you to organize your thoughts and

pick out the important facts. It also helped you to identify, which details go with each other. However, the poem did help me to visualize the science concepts better. This is because when you write a poem, you use a lot of creativity. In my creativity I used a lot of analogies. These analogies tied things that I am very familiar with to things I was not familiar with.

The student interviews provided sound evidence that was in alignment with the data collected on student surveys and observed by the Principal Investigator.

In the journal kept by the Principal Investigator it was noted that the collective amount of time that students spent on brainstorming prior to writing the poem was longer than the amount of time used for brainstorming during the essay. However, more students finished writing the science poems faster than writing the essays. There also seemed to be more “light bulb” moments when students were sharing their poems with one another once the poems were redistributed after grading. Students were generally commenting out loud to one another and then asking each other what analogies they used in their poems. Statement such as ... “so x is like y?, I get it now” were being shared in multiple class sections.

The Principal Investigator also noted that students also commented on the fact that their level of understanding was pushed when studying prior to writing a poem. Additionally, some students felt compelled to rhyme the lines of the poem and this seemed to increase the difficulty level.

After writing the first two poems and two essays, the Principal Investigator had an increased number of students stopping by before school, at the lunch hour, or after school wanting feedback on new and unique analogies that they developed. This may be attributed to the fact that the final two essays and poems were being written without the use of notes or

additional resources and students wanted to secure their knowledge before their work was scored. Furthermore, the difficulty level of the concepts was increasing by the nature of the subject matter and students had limited background knowledge on the final two essay /poem topics when compared to the first two topics. Writing the poems for the final two topics seemed to be more challenging, however, once students were able to find a strong working analogy the poetry writing process seemed to become easier. The amount of writing and the process of technical science writing for some students was a new phenomenon. Students claimed that they have done science writing in the past, however, it was not as intense, sustained, or as regular as it was in the biology honors course this year.

INTERPRETATION AND CONCLUSION

This research study has begun to affirm the primary research question; scientific poetic response may be used to demonstrate content mastery & understanding of advanced biological concepts. Despite the fact that Part I of the study did not yield significant results, Part II of the study provided evidence that content mastery of the scientific poetic response is just as good as that of the science essay. It has been demonstrated through this research investigation that there are some intersections and interactions across the two domains of science and poetry that may assist students in comprehension of difficult abstract scientific material. The integration of technical scientific vocabulary to further language specificity and precision, as well as the integration of qualitative and quantitative data expressed in a poetic form according to some students provides them the opportunity to visualize and chunk the biological concepts in order to assist them in revealing their personal scientific

understanding. One student in particular, Jvy, claimed that “writing a science poem forced me to study harder and think about the concept in a whole new way.” After making such a proclamation, several of his classmates shook their heads in agreement and added that at first, they were caught up in the writing the poem, but then after a while they overcame this and were able to focus on developing analogies that gave them the chance to better understand the science than ever before. Even in the Principal Investigator’s journal entries revealed how it appeared that students seemed to be thinking differently during the writing process when developing a science poem as opposed to writing an essay.

It seems as though scientific poetic response has the potential to engage some scientifically and poetically minded students. Furthermore, it can allow students to exhibit knowledge through methods of understanding on the levels of creative, critical, and metaphoric thinking in ways that the traditional five-paragraph essay may not be able to achieve as a standalone open-ended assessment. This research therefore also affirms the secondary research question of this investigation; scientific poetic response can be an alternative yet effective method of summative assessment. The results of this investigation seem to support the work of Goubeaud, who suggested that by offering students an open-ended assessment where learners are better able to demonstrate content mastery assessments can function as measurement tools beyond that of pure evaluation (Goubeaud, 2010). Science poetry may in fact be such an assessment tool. In fact science poetry may be able to serve as both a formative and summative assessment tool by allowing for cognitive chunking and visualization as well as to display a level of content understanding.

When reflecting upon the impact of infusing science poetry into an honors biology curriculum, this research seems to meet the goal established by the committee on Classroom

Assessment and the National Science Education Standards back in 2001 in its attempt to continue to move away from traditional assessment practices and engage in assessment that allows students to make connections between their understandings of the natural world and the current knowledge and theories accepted by the greater scientific community. In doing so, the generation of a science poem could potential emerge as a means by which to strengthen assessment in the science classroom so that students learn from assessments in which they are engaged. In doing so the science poem allows for the student to unpack the abstract and complex nature of science and display interconnectedness through analogies, similes, and metaphors to expand a student's learning.

VALUE

Science poetry is a tangible means to help learners develop and anchor theoretical constructs. The use of poetry in the biology classroom informs, engages and enhances students' understanding of abstract and complex scientific theories, concepts, and technical vocabulary. In a January 2012 publication of *The Science Teacher*, the principle focus of the issue was Science and Literacy. Steve Metz, the field editor reinforced the goals of the recently released Framework for K-12 Science Education which strives to increase content knowledge and communicate evidence of concrete scientific understandings. Science Poetry as demonstrated by this investigation can meet these goals. Science poetry has a place in the classroom. It gives students the opportunity to have multiple vantage points of a concept. It is not enough to just merely develop an eye for science, but rather it is important to articulate and interpret one's observations. Poetry provides an alternative avenue to allow for this to occur. Poetry embraces the use of literary techniques such as simile, analogy, and metaphor,

and when used in the science classroom can permit a student to capture their scientific awareness and enrapture strong emotional reactions, yet still allow the author to connect with and inform the reader of various aspects of scientific phenomenon. Offering learners an opportunity to reveal their understanding and mastery of complex biological concepts through scientific poetic response (the creation of a science poem) may just in fact be the much-needed scientific conceptual metacognitive summative assessment that many students and teachers have come to need.

The action research process has given me the opportunity to reflect upon my instructional practices as an educator. I have become more confident in my ability to vary instructional practices after journaling and reflecting. I have also become more aware of how my students learn and what instructional practices they have a tendency to like and dislike. Talking with my students openly about teaching and learning has had a positive impact on my student / teacher relationships this school year. Students seem more comfortable about communicating honestly about what is personally working for them in the learning process and what is not. I in turn feel more confident about trying new teaching strategies with my students. After conducting this action research investigation I hope to continue to modify and enhance my instructional practices and strengthen my communications with students in order to positively contribute to the field of education and assist students in meeting their educational goals.

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APPENDICES

APPENDIX A

RESEARCH PARTICIPANT LETTER


Morristown High School

 Science Department / Science Academy 50 Early Street, Morristown, NJ 07960-3898

September 3, 2011

Dear Parents/ Guardians,

The mission of the Morris School District is to prepare students for responsible citizenship and to inspire students to perform to their full potential. Our Principal, Mrs. Linda Murphy as well as the other administrators at Morristown High School have encouraged teachers to make student-centered learning an instructional priority this school year. They have defined *student-centered learning as providing students with personalized learning experiences in which they are provided more choice in decision making about what and how they learn.* Furthermore, they have acknowledged that *students learn by doing and by performing tasks that are relevant and meaningful.*

I firmly agree with the direction that is being embraced by my administrators and have spent my career shaping the education that I provide in my classroom for students to embrace cross-curricular student centered learning. This school year, as part of my professional plan and graduate research through Montana State University, I will be running an action research study through my honors biology classes. I have spent time with members of the faculty and staff reviewing my intentions and have based my ideas on research that I have conducted over the past four years with students exploring the commonalities shared by both the domains of science and literature; specifically poetry.

As concrete as science is, it is a subject matter that is often difficult to understand because of the multifaceted concepts and technical vocabulary that is deeply rooted in so many of the abstract, yet fundamental, ideas that surround the essence of the subject matter. Often times advanced science is studied in a closed environment where access to experiences is limited. When learners do not have an opportunity to physically discover or readily connect with advanced scientific concepts the complexity of the topics being explored increases and true understanding cannot be guaranteed. This lack of accessibility forces a need for a more tangible means to be utilized in order to help learners develop and anchor theoretical constructs.

This school year I will teach my students how to use descriptive language techniques such as metaphor, simile, and visual/sensory imagery to illustrate scientific concepts. As advanced abstract biological concepts are revealed throughout the course, students will be introduced to scientific poetry, literature, and art that incorporates descriptive language techniques to assist in expanding a student's foundational knowledge on various biological topics. At the conclusion of each conceptual unit, students will be given several different options to choose from in order to display their understanding of selected biological concepts.

So please join me on this journey to assist your child in embracing cross-curricular student centered learning. If you should desire any further information or background at any point in time, please do not hesitate to contact me by phone (973) 292-2000 ext. 2174 or by e-mail: erin.colfax@morristownhighschool.org

Thank you,

Mrs. E. Colfax Biology Teacher

APPENDIX B

TRADITIONAL SCIENCE ESSAY RESPONSE TECHNIQUES

Morristown High School
Biology Department
Traditional Science Essay Response Techniques



Traditional Essay Response Assessments in biology are used to assess your mastery of scientific concepts, by having you apply what you have learned, break down specific concepts, and bring ideas together in new and different ways. The components of the typical “Language Arts five paragraph essay” should be embraced when generating a science essay response. However, this basic format in science may require you to additionally draw graphs / tables / diagrams.

Paragraph 1: Introduction: start by establishing the theme of the essay by re-stating the task or question, thesis statement (hypothesis statement: If / then statement), provide background information, and introduce the points that you will be covering in the body paragraphs.

Paragraphs 2, 3, 4: Body: start by establishing a topic sentence for each of the paragraphs, connect your ideas to scientific concepts & theories, integrate topic specific vocabulary, use topic specific examples, and draw upon prompt information and your previous knowledge. *Overall, each paragraph should have accurate, reflective responses that are supported by sufficient specific details.*

Paragraph 5: Conclusion: start by re-stating your thesis statement (hypothesis statement: If / then statement) that was introduced in paragraph 1. Then affirm or reject the thesis statement (hypothesis statement) when appropriate. Finish up by summarizing all of the points covered in the body paragraphs. *Be sure to avoid introducing new information.*

Tables / Graphs / Diagrams

Use titles, identify units, accurately insert data, clearly & concisely display data, erase fully when you make an error, and consider using the edge of the testing booklet for drawing straight lines.

The rules of language arts and writing extend far beyond that of English class. Writing in science class is essential when you want to share your level of comprehension and understanding. By following the basic rules of writing you are able to organize your thoughts and communicate your ability to understand, analyze, and synthesize information in new and different ways.

- *Brainstorm first.
- *Use appropriate transitions between paragraphs.
- *Read over and edit work; (proofread for spelling, grammar, punctuation, capitalization, and sentence structure).
- *Read over your essay response silently to yourself to check for organization of thought.
- *Use your best handwriting, consider printing, and remember to write in English

APPENDIX C

DESCRIPTIVE LANGUAGE TECHNIQUES

Descriptive Language Techniques: Biology Honors 2011-2012
Your guide to generating a scientific poetic response

YOUR SCIENTIFIC UNDERSTANDING WILL INCREASE WHEN YOU COMBINE YOUR ABILITY TO OBSERVE WITH LITERARY MECHANISMS IN ORDER TO MAKE ABSTRACT SCIENTIFIC CONCEPTS MORE CONCRETE.

- YOUR STUDY OF BIOLOGY IS ABOUT SIGHT...*SEEING THROUGH THE EYES OF THE SCIENTIST AND POET*



- YOUR STUDY OF BIOLOGY IS ABOUT SOUND...*HEARING THROUGH THE EARS OF SCIENTIST AND POET*



- YOUR STUDY OF BIOLOGY IS ABOUT TASTE...*TASTING AND SPEAKING THROUGH THE MOUTH OF A SCIENTIST AND POET*
- YOUR STUDY OF BIOLOGY IS ABOUT ...*TOUCHING THE WORLD THROUGH THE HANDS OF A SCIENTIST AND POET*
- YOUR STUDY OF BIOLOGY IS ABOUT ...*SMELLING THE WORLD THROUGH THE NOSE OF A SCIENTIST AND POET*

YOUR STUDY OF BIOLOGY WILL ALLOW YOU TO MAKE CONNECTIONS BETWEEN THE SCIENTIFIC CONCEPTS AND THE NATURAL WORLD.

YOUR STUDY OF BIOLOGY IS ABOUT SYNERGY... SCIENCE PLUS POETRY = SYNERGY!!!

YOUR STUDY OF BIOLOGY IS ABOUT FORGING... COMMON GROUND BETWEEN THE SCIENTIFIC AND LITERARY WORLDS

“IMAGINATION IS MORE IMPORTANT THAN KNOWLEDGE”

Albert Einstein

IMAGINATION

CREATIVITY

AMBIGUITY METAPHOR

RHETORICAL PROGRESSION

- **DESCRIBE**... a scientific phenomenon, theory, principle, or experience presenting the quantitative facts and data with specific scientific details and vocabulary. Use science as starting point.
- **CONNECT/ASSOCIATE/LEAP**...from the scientific to the self or human dimension of experience. Use science as metaphor.

- **REFLECT/MEDITATE**... on the meaning or consequences of the phenomenon or experience.

Science can become more concrete when we move from the literal *meaning to the metaphoric, symbolic or figurative*.

4 POETIC STANCES: ANY USE OF THESE MAKES IT POETRY

- DESCRIBE...POET DESCRIBES THE SUBJECT WITH SPECIFIC DETAILS
- ADDRESS... POET SPEAKS TO THE SUBJECT IN THE POEM...(YOU)
- PERSONA... POET TAKES ON THE IDENTITY OF THE SUBJECT (I)
- STANCE BLENDING...POET USES MULTIPLE STANCES IN THE POEM.

HOW TO WRITE A SCIENCE POEM

STEP ONE: THE SCIENCE PART

GATHERING QUANTITATIVE DATA AND TECHNICAL VOCABULARY

AMBER

GENERAL DESCRIPTION: Amber $C_{10}H_{16}O$ (variable)

Amber is a fossil resin that is frequently clouded and can contain fossil insects or parts of plant debris; it is the fossilized resin from pine trees. It occurs in young sedimentary rocks of estuarine origin or beach deposits. Found in countries around the Baltic Sea, Romania and Siberia.

ID FACT FILE:

CRYSTAL SYSTEM: Amorphous

COLOR: Orangey yellow to brown

WHERE: Sedimentary

ABUNDANCE: Restricted

FORM: Nodular

CLEAVAGE: None

HARDNESS: 2-2.5

SPECIFIC GRAVITY: 1.1.-1.3

LUSTER: Greasy, resinous

TRANSPARENCY: Transparent to Opaque

TESTS: Conchoidal fracture. White streak

LOOK ALIKES: None; Unlikely to be mistaken

STEP TWO: THE POETRY PART
DETERMINING THE QUALITATIVE DATA

- **DESCRIBE...POET DESCRIBES THE SUBJECT WITH SPECIFIC DETAILS**
- **ADDRESS... POET SPEAKS TO THE SUBJECT IN THE POEM...(YOU)**
- **PERSONA... POET TAKES ON THE IDENTITY OF THE SUBJECT (I)**
- **STANCE BLENDING...POET USES MULTIPLE STANCES IN THE POEM.**

STEP THREE: BRINGING IT ALL TOGETHER

**EXAMPLE POEMS WRITTEN BY POET: NANCY GORRELL FOR EACH OF
THE POETIC STANCES...**

DESCRIBING...

A fossil resin frequently found
Around the Baltic Sea or young sedimentary ground,
Frequently clouded, orange-yellow or brown,
Amber has secrets inside which abound...

ADDRESSING...

To the Cricket in the Amber
Oh, how does it feel to be inside
The resin walls of amber tide?
Hidden in its transparency
A fossil from here to eternity.
Do you wish you could escape

**Back to the pines when the earth did quake?
To sing your song to the Baltic Sea
Once again a cricket free.**

APPENDIX 3: Descriptive Language Techniques (page 5)

PERSONA

**Amber
I am amorphous, resinous and greasy,
I flow from piney trees
Catching insects and plant debris,
With nodular ease.**

**Some think I am quite wicked;
Others think I am good luck
Whatever you might think of me,
If you're in my way you will get stuck.**

BLENDING STANCES...

The Cricket in the Amber

**The cricket
would like to fly back
into the piney wood.
weary of all the gazers
he would shout, if only he could...**

**I am not a fossil resin
Frozen in ancient time
I have a voice of my own
And it can cry and rhyme**

**Oh cricket in the amber!
How sad it seems to be,
That only those with empathy
Can hear your soulful plea.**

(Gorrell, 2008)

WHAT IS A SCIENCE POEM?

A POEM WHICH IS INSPIRED BY AND/OR INFORMED BY SCIENTIFIC FACTS, PHENOMENA, PRINCIPLES, QUESTIONS, OBSERVATIONS, AND EXPERIENCE.

A POEM WHICH UTILIZES QUANTITATIVE AND QUALITATIVE DATA TO DESCRIBE SCIENTIFIC PHENOMENA, PRINCIPLES, QUESTIONS, AND OBSERVATIONS AND EXPERIENCE.

A POEM WHICH IS SCIENCE-SUBJECT BASED, UTILIZING SCIENTIFIC VOCABULARY, CONCEPTS, PRINCIPLES AND KNOWLEDGE. *THE POEM APPEARS TO BE ABOUT SCIENCE AT FIRST, BUT THEN 'LEAPS' TO SAY SOMETHING MORE.*

EXEMPLAR POEM WRITTEN BY POET: ERIN COLFAX
--

Water's Compositional Secrets

Hydrogen and Oxygen you look so beautiful compounded together beneath this aqua marine surface.

Your polar covalent bondage allows me to see the many shapes you can form.

As tiny molecular droplets you cling to one another like beads on a smooth surface.

Your attraction to foreign objects makes the world below look like a canvas that rises up against the force of gravity.

You protect those living within from drastic changes impressed upon you like a mother protecting its young.

There are days when I envy the simple alteration that can be made to your inner core...

Those times when you get to reinvent yourself and adjust your external appearance

Those times when your internal energy redefines your state of being

But today, I simply embrace the peacefulness that you bring as I dive through you and smile knowing your compositional secrets.

APPENDIX D

STUDY SPECIFIC HOLISTIC SCIENCE WRITING ASSESSMENT RUBRIC

“A” Mastery Level of Command: Outstanding Science Writing (5/5pts.)

- Evidence of meaningful fusion of science and written expression by employing 5 or

more techniques of William's Taxonomy of Creative Thought: fluency, flexibility, originality, elaboration, risk taking, complexity, curiosity, & imagination.

- Exhibits scientific knowledge by employing and defining a minimum of 5 specific and appropriate scientific vocabulary terms.
- Explains scientific concepts using a combination of multiple metaphors, similes, or analogies.
- Demonstrates complex scientific knowledge by accurately applying, analyzing, and synthesizing concepts.
- Integrates and explains multiple examples in order to show the scientific process.
- Demonstrates and uses accurate, specific, and plentiful qualitative and quantitative data.
- Presents a clear organization of thought with respect to the science concept.
- Makes multiple related connections to extend the science concept.
- Proofreading has taken place; there are limited to no minor errors existing in spelling, grammar, punctuation, or capitalization.

“B” Proficient Level of Command: Solid Science Writing (4/5pts.)

- Evidence of meaningful fusion of science and written expression by employing 1-3 techniques of William's Taxonomy of Creative Thought: fluency, flexibility, originality, elaboration, risk taking, complexity, curiosity, & imagination.
- Exhibits scientific knowledge by employing and defining 3-5 specific and appropriate scientific vocabulary terms.
- Explains scientific concepts using a combination of metaphors, similes, or analogies.
- Demonstrates scientific knowledge by applying and analyzing, concepts.
- Uses examples in order to show the scientific process.
- Integrates data.
- Organization of thought is attempted in respect to the science concept.
- Makes related connections to extend the science concept.
- Proofreading needs to take place; there are some minor errors existing in spelling, grammar, punctuation, or capitalization.

“C” General Level of Command: Satisfactory Science Writing (3/5pts.)

- Traditional presentation of the topic.
- Limited evidence of meaningful fusion of science and written expression.
- Emerging scientific knowledge by employing vocabulary terms.
- Attempts to explain scientific concepts using appropriate metaphors, similes, or analogies but some may be unsuccessful or inaccurate.
- Demonstrates knowledge by referencing a limited number of examples or inappropriately uses examples in order to attempt to show the scientific process.
- Evidence to clearly explain the concept is missing.
- References limited data.
- Limited organization of thought; confusion exists in the explanation process.
- Proofreading needs to take place; there are multiple major errors existing in spelling, grammar, punctuation, and/or capitalization that impede understanding.

“D” Incompetent Level of Command: Weak Science Writing (2/5pts.)

- Traditional presentation of the topic.
- Lacks evidence of meaningful fusion of science and written expression Emerging scientific knowledge by employing vocabulary terms.
- Fails to exhibit scientific knowledge accurately.
- Inappropriately uses vocabulary or examples or uses vocabulary or examples that are not connected to the topic.
- Does not integrate data / facts.
- Disorganized thoughts; confusion exists in the explanation process.
- Proofreading needs to take place; there are multiple major errors existing in spelling, grammar, punctuation, and/or capitalization that significantly impede understanding.

“F” No Level of Command: No Evidence of Science Writing (0/5pts.)

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Science Grader Score		English Grader Score		Third Party Scorer

APPENDIX E

WRITING PROMPTS



Name: _____
Biology Honors

Date: _____
Block: _____

This is a content specific holistic science writing assessment. Write a poem about the organelles and inner workings of the eukaryotic cell that integrates descriptive language techniques such as metaphor, simile, and visual/sensory imagery to illustrate the biological concepts in order to better visualize and connect with concepts being assessed. Use the descriptive language techniques packet to help guide your writing. Additionally you may use the Biology textbook, your notes, or the Internet to further your writing and extend the concepts being assessed. Your poem will be assessed using the Study Specific Holistic Science Writing Assessment Rubric.

This is a content specific holistic science writing assessment. Write a five paragraph essay about the organelles and inner workings of the eukaryotic cell that integrates descriptive language techniques such as metaphor, simile, and visual/sensory imagery to illustrate the biological concepts in order to better visualize and connect with concepts being assessed. Use the Essay response techniques to help guide your writing. Additionally you may use the biology textbook, your notes, or the Internet to further your writing and extend the concepts being assessed. Your essay will be assessed using the Study Specific Holistic Science Writing Assessment Rubric.



Name: _____
Biology Honors

Date: _____
Block: _____

This is a content specific holistic science writing assessment. Write a poem about the processes of photosynthesis and cellular respiration. These two processes work together in order to provide the energy that the earth's ecosystem needs to function properly. Examine the two processes and explain the relationship between the two by integrating descriptive language techniques such as metaphor, simile, and visual/sensory imagery to illustrate the biological concepts in order to better visualize and connect with concepts being assessed. Be sure to identify what each process does, where each process takes place, the molecules that are involved, and why one is necessary for the other to occur. Use the descriptive language techniques packet to help guide your writing. Additionally you may use the Biology textbook, your notes, or the Internet to further your writing and extend the concepts being assessed. Your poem will be assessed using the Study Specific Holistic Science Writing Assessment Rubric.

This is a content specific holistic science writing assessment. Write a five-paragraph essay about the processes of photosynthesis and cellular respiration. These two processes work together in order to provide the energy that the earth's ecosystem needs to function properly. Examine the two processes and explain the relationship between the two by integrating descriptive language techniques such as metaphor, simile, and visual/sensory imagery to illustrate the biological concepts in order to better visualize and connect with concepts being assessed. Be sure to identify what each process does, where each process takes place, the molecules that are involved, and why one is necessary for the other to occur. Use the Essay response techniques to help guide your writing. Additionally you may use the biology textbook, your notes, or the Internet to further your writing and extend the concepts being assessed. Your essay will be assessed using the Study Specific Holistic Science Writing Assessment Rubric.



Name: _____
Biology Honors

Date: _____
Block: _____

This is a content specific holistic science writing assessment. Write a poem about the molecule of DNA and its method of replication. Consider the role of DNA in heredity; its ability to store information, replicate itself, and transmit information from one generation to the next. Examine the structural components of DNA, the double helix model, the replication process, the role of key enzymes, and the influential scientists that solved the structure of DNA by integrating descriptive language techniques such as metaphor, simile, and visual/sensory imagery. Recall the descriptive language techniques you were introduced to through the packet to help guide your writing. Your poem will be assessed using the Study Specific Holistic Science Writing Assessment Rubric.

This is a content specific holistic science writing assessment. Write a five-paragraph essay about the molecule of DNA and its method of replication. Consider the role of DNA in heredity; its ability to store information, replicate itself, and transmit information from one generation to the next. Examine the structural components of DNA, the double helix model, the replication process, the role of key enzymes, and the influential scientists that solved the structure of DNA by integrating descriptive language techniques such as metaphor, simile, and visual/sensory imagery. Recall the Essay response techniques to help guide your writing. Your essay will be assessed using the Study Specific Holistic Science Writing Assessment Rubric.



Name: _____
Biology Honors

Date: _____
Block: _____

This is a content specific holistic science writing assessment. Write a poem about the process and importance of protein synthesis in organisms. Specifically address the progression of transcription and translation in order to generate proteins that meet the organism's needs. Consider the role and actions of: DNA, mRNA, rRNA, tRNA, codons, anticodons by integrating descriptive language techniques such as metaphor, simile, and visual/sensory imagery. Recall the descriptive language techniques you were introduced to through the packet to help guide your writing. Your poem will be assessed using the Study Specific Holistic Science Writing Assessment Rubric.

This is a content specific holistic science writing assessment. Write a five-paragraph essay about the process and importance of protein synthesis in organisms. Specifically address the progression of transcription and translation in order to generate proteins that meet the organism's needs. Consider the role and actions of: DNA, mRNA, rRNA, tRNA, codons, anticodons by integrating descriptive language techniques such as metaphor, simile, and visual/sensory imagery. Recall the Essay response techniques to help guide your writing. Your essay will be assessed using the Study Specific Holistic Science Writing Assessment Rubric.

APPENDIX F

SCIENCE WRITING PRE-STUDY SURVEY

Participation in this research survey is voluntary and participation or non-participation will not affect a student's grades or class standing in any way.

Name: _____

Date: _____

ID #: _____

Period: _____

Gender: _____

Age: _____

Middle School Attended: _____

What level English course are you currently enrolled in? _____

1. How do you feel about science?
- ☐ Science is my favorite subject
 - ☐ I like science
 - ☐ I am indifferent about science
 - ☐ I do not like science

Do you think science is important? Explain.

2. Have you ever done any science writing?

☐ Yes ☐ No

If so, what type of science writing (i.e. poetry, essays, non-fiction, fiction, songs)?

3. If you could pick any type of science to study, what would it be? Why?

☐ Earth Science
☐ Chemistry
☐ Physics
☐ Biology
☐ Engineering
☐ Anatomy / Physiology
☐ Computer Science
☐ Other: _____

4. Do you think that there is a crossover between science and other subjects?

☐ Yes ☐ No

If so, which ones?

☐ Math
☐ English
☐ History
☐ Phys. Ed / Health
☐ Foreign Language
☐ Art
☐ Music
☐ Other: _____

5. Are you more interested in science / math classes or humanities classes (English/history)?

APPENDIX 6: Science Writing Pre-study survey (page 2)

6. Prior to biology honors, have you ever read a poem in science class before?
☐ Yes
☐ No
7. Prior to biology honors, have you ever written a poem in science class before?
☐ Yes
☐ No

8. Have you ever been exposed to poetry in school before this year in biology?
☐ Yes
☐ No

If so, in what class / classes?

- ☐ Math
☐ English
☐ History
☐ Phys. Ed / Health
☐ Foreign Language
☐ Art
☐ Music
☐ Other: _____
9. Do you like to read poetry?
☐ Yes ☐ No

Why or why not?

10. Do you like to write poetry?
☐ Yes ☐ No
- Why or why not?
-

11. Have you ever been assigned to write a poem prior to biology honors?
☐ Yes
☐ No
- If so, in what class / classes?
☐ Math
☐ English
☐ History
☐ Phys. Ed / Health
☐ Foreign Language
☐ Art
☐ Music
☐ Other: _____

12. Have you ever been instructed on how to write a poem?

☐ Yes

☐ No

Who or in what class provided the instruction?

13. Would you have any interest in an opportunity to write a science poem in place of a traditional quiz assessment of multiple choice, fill-in the blank, true / false?

☐ Yes

☐ No

Why or why not?

APPENDIX G

SCIENCE WRITING POST-STUDY SURVEY

Participation in this research survey is voluntary and participation or non-participation will not affect a student's grades or class standing in any way.

Name: _____

Date: _____

ID #: _____

Period: _____

Gender: _____

Age: _____

1. Did you find the integration of poetry into the learning process to be distracting?
(Please circle your choice)

**Very distracting Moderately distracting Neither Minimally
Distracting Not distracting**

Please explain your answer.

2. Did you find the integration of poetry to be helpful to your learning /
understanding of science concepts? (Please circle your choice)

**Very helpful Moderately helpful Neither Minimally
helpful Not helpful**

Please explain your answer.

3. Did you feel that writing the essay helped you to break down the concept into
meaningful chunks of information?

- ☐ Yes
☐ No

Please explain your answer.

4. Did you feel that writing the poem helped you to break down the concept into
meaningful chunks of information?

- ☐ Yes
☐ No

Please explain your answer.

5. Did the poem allow you to better visualize the science concepts?

- ☐ Yes
☐ No

Please explain your answer.

6. Did the creation of the **poem** confuse you more about the science concepts?

☐ Yes

☐ No

Please explain your answer.

7. Did the **essay** allow you to better visualize the science concepts?

☐ Yes

☐ No

Please explain your answer.

8. Did the writing of the **essay** confuse you more about the science concepts?

☐ Yes

☐ No

Please explain your answer.

9. Did the **rubric** allow you to focus your writing of the essays and poems more effectively?

☐ Yes

☐ No

Please explain your answer.

10. Did you prefer to write an essay or a poem for your summative assessments?

☐ Essay

☐ Poem

Please explain your answer.

APPENDIX H

SCIENCE WRITING ESSAY EXEMPLAR

Author: Alana Levine

Science Writing Essay: *Weather vs. Climate*

Question: Describe the similarities and differences between weather and climate.

Response: There are many similarities and differences between climate and weather. Weather is defined as a state of the air at a specific time and place. On the other hand, climate pertains to a generalization of conditions in an area over a span of thirty or more years. If the weather is measured by the day-to-day state of the Earth's atmosphere, then the climate is dependent on the weather conditions in a specific region, over a thirty-year period. Weather and climate are similar with regards to how they relate and how greenhouse gases affect them. They differ in terms of what they represent, the instruments used to measure them, and how they are studied.

Look around you; the weather is constantly changing. The weather is based on many determining factors that affect it on a daily bases. Since weather is dependent on the movement of the air in our atmosphere, it is constantly changing. Weather is made up of wind-speed, air pressure, temperature, dew point, and humidity. Many different instruments are used to measure the weather's properties. For example, air pressure is measured using a barometer. The higher the barometer is, the fairer the weather is. The lower the barometer is the less fair weather.

Climate is a collaboration of weather patterns over a long time frame. It is based on a scale of about thirty years. Even though it is an average representation of temperature and precipitation over a long amount of time, it can still vary within a region. Trapped solar energy, transport of heat by wind, latitude, and the transfer of heat by ocean currents are all major factors that play into climate. For instance, when determining the climate based on the latitude, the closer a region is to the North and South poles, the colder it is. On the contrary, the farther away a region is from the North and South poles, and the closer it is to the equator, the warmer the region is.

When one compares and contrasts weather and climate, there are many prominent similarities and notable differences. One way that they compare is in terms of their relationship and climate's dependence on weather. For instance, climate is a statistical semblance of changing weather patterns in a given area for a set amount of years. Another way that climate and weather are similar is how they both rely on the use of various tools and instruments to predict their turnout. For instance, without the use of these instruments, both weather and climate would not be capable of being predicted. Furthermore, both climate and weather are affected by CO₂, H₂O, and methane. Conversely, weather and climate differ in many ways. For example, weather is the condition of the atmosphere on a daily bases, whereas climate is a gathering of weather patterns over a set amount of time. Additionally, weather and climate vary in terms of how they are studied. Weather is observed through Meteorology, the study of the changes in temperature, air pressure, moisture, and wind direction in the troposphere. On the other hand, climate is observed through climatology, the study of the weather and its changes over long periods of time.

If the weather is a daily representation of the atmosphere on Earth, then climate is a collaboration of weather patterns over a thirty-year period. Weather and climate compare in terms of how they both share a dependent relationship between one another and how greenhouse gases affect them both. They differ in terms of the instruments used to measure them, what they represent, and the methods of how they are studied. Overall, there are many evident similarities and differences between weather and climate.

APPENDIX I

SCIENCE QUIZ: PH / WATER

1. Draw one water molecule and provide a thorough explanation of the bond holding the molecule together.

2. Select the specific property of water that allows water to reach the top of trees by moving up the trunk?

a. Cohesion

b. Adhesion

c. Surface Tension

d. Capillary Action

e. Inhibition

3. What properties of water justify certain insects being able to walk across the surface of water without falling through?

4. Based on what you know, how would you explain water's ability to "bead up" on the outside of an umbrella?

5. Match the given pH readings to the proper classification...

pH =2,

pH =7

pH =11

Base

Acid

Neutral

6. Provide me with a logarithmic mathematical explanation for a substance that has a pH of 2.

7. When a chemical such HBr is added to a beaker of water, what will happen?

8. When a substance is deemed as Alkaline, does that mean it is an acid, a base, or neutral?

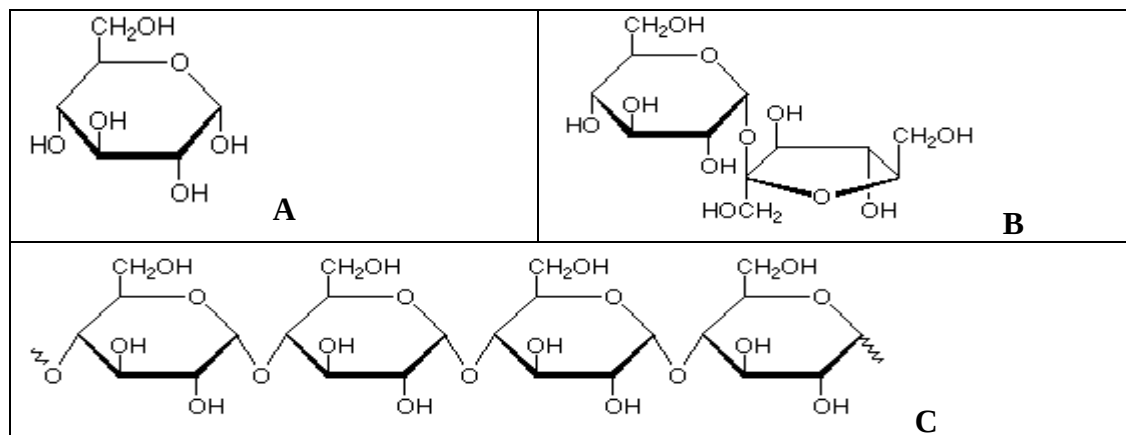
9. If NaOH is added to a solution, what part of the molecule will dissociate to make the solution basic?

10. What can be done to neutralize a solution that has a pH of 3?

APPENDIX J

SCIENCE QUIZ: CARBOHYDRATES

1. Which molecule is a monosaccharide? _____



2. **Outline and name the process** of creating a molecule similar to “A” below when one molecule of “B” is broken apart.

3. Think of the classification for each of the following carbohydrates. i.e. monosaccharide, disaccharide, polysaccharide

- a. Glucose = _____
- b. Lactose = _____
- c. Starch = _____

4. How are monosaccharides different from one another if they all have the same molecular formula?

5. What process must plants undergo in order to **produce** carbohydrates?

6. What process do plants and animals undergo in order to **use** carbohydrates as a fuel source?

7. When two monosaccharides are joined together what type of bonds hold this new molecule together?

8. In what form do animals store starch in their muscles and liver?

9. Make a distinction between the carbohydrates found in the following foods... table sugar, grapes, pasta _____

10. Provide a practical use of the knowledge that you have learned regarding carbohydrates...

APPENDIX K

SCIENCE QUIZ: ECOLOGY 1

_____ 1. Ecology is the study of the interaction of living organisms

- a. with each other and their habitat.
- b. and their communities.
- c. with each other and their physical environment.
- d. and the food they eat

_____ 2. How do most primary consumers obtain their own food?

- a. By using light energy to make carbohydrates
- b. By changing water into carbon dioxide
- c. By consuming an organism uses light or chemical energy to make their own food
- d. By consuming an organism that consumed an organism that used light or chemical energy to make their own food

_____ 3. Select the abiotic factor...

- a. snow.
- b. plants.
- c. fungus.
- d. animals.

_____ 4. A organism that eats only producers?

- a. herbivore.
- b. Omnivore
- c. carnivore
- d. autotroph

_____ 5. A turkey vulture that flies through the air and looks for dead animals to feast on. Based on its behavior, which pair of ecological terms describes the bird?

- a. Herbivore, decomposer
- b. Omnivore, consumer
- c. Scavenger, consumer
- d. Detritivore, consumer

_____ 6. All the interconnected feeding relationships in an ecosystem make up a food... .

- a. Network
- b. Chain
- c. Web
- d. Network

_____ 7. Carbon cycles through the biosphere in all of the following processes except...

- a. Decomposition of plants and animals
- b. Evaporation
- c. Photosynthesis
- d. Burning of fossil fuels

Biogeochemical cycle

The diagram illustrates the Nitrogen Cycle with the following components and processes:

- Atmosphere:** Gaseous Nitrogen (N_2 , NO_x) and a sun.
- Soil:** Precipitation (rain), Organic Residues, Organic Matter (e.g., CH_4), Ammonium Nitrate (NH_4^+), Nitrate (NO_3^-), and Soil Bacteria.
- Living Organisms:** Plants (trees), a cow, and a rabbit.
- Processes:**
 - Denitrification:** Conversion of nitrate back into gaseous nitrogen.
 - Plant Consumption:** Uptake of nitrogen by plants.
 - Herbivory:** Consumption of plants by a rabbit.
 - Ammonification:** Decomposition of organic matter into ammonium.
 - Nitrification:** Conversion of ammonium into nitrate.
 - Leaching:** Movement of nitrate out of the soil.

9. The movements of energy and nutrients through a living system are different because?
- a. Energy is limited in the biosphere and nutrients are always available
- b. Energy flows in one direct and nutrients get recycled
- c. Energy is limited in the biosphere and nutrients are always available
- d. Nutrients flow in two directions and energy is recycled

- Birds
- Tree
- Owl
- Bear

cougar

bear

fox

owl

deer

rodent

birds

- _____ 12. Which statement about the organization of an ecosystem is correct?

13. In a four-leveled energy pyramid, if the first level contains 6000 calories of energy, the fourth level will contain how much energy?

15. Which biogeochemical cycle consists of three distinct parts: ammonification, nitrification, and assimilation?

APPENDIX L

SCIENCE QUIZ: ECOLOGY 2A

1. _____ What term means . . . the movement of organisms that would cause a population decrease?
 - a. Growth Rate
 - b. Population Density
 - c. Immigration
 - d. Emigration
2. _____ What term means . . . the rate of death of individuals in a given population?
 - a. Population Density
 - b. Dispersion
 - c. Mortality Rate
 - d. Growth Rate
3. _____ Which factor is a limiting factor on the growth rate of a population?
 - a. Food Resources
 - b. Time
 - c. The number of abiotic factors
 - d. Organism size
4. _____ The process of gradual change from one community of organisms to another is called?
 - a. Biome
 - b. Ecological Succession
 - c. Pioneer Community
 - d. Biosphere
5. _____ Scientists refer to the world's major communities as?
 - a. Successive States
 - b. Biomes
 - c. Communities
 - d. Ecosystem
6. _____ What is the name of the biome in which grazing animals live?
 - a. Tropical Rain Forest
 - b. Temperate Deciduous Forest
 - c. Taiga
 - d. Savannah
7. _____ What do scientists refer to as the count of a number of species in a given area?
 - a. Population
 - b. Biosphere
 - c. Ecosystem
 - d. Community
8. _____ What term is given to all of the different species that move out of a population?
 - a. Immigration
 - b. Emigration
 - c. Growth Rate
9. _____ The largest number of organisms that an environment can support is called?
 - a. Limiting Factor
 - b. Population Density
 - c. Carrying Capacity
 - d. Maximum population
10. _____ What do scientists call the number of individuals in a given area?
 - a. Limiting Factor
 - b. Population Density
 - c. Carrying Capacity
 - d. Maximum population
11. _____ What term refers to abiotic factors in an environment that restrict the number of individuals in a population?
 - a. Limiting Factor
 - b. Population Density
 - c. Carrying Capacity
 - d. Maximum population
12. _____ Find the Biome that has the divisions of semi-arid, coastal, hot/dry.
 - a. Tundra
 - b. Marine
 - c. Desert
 - d. Forest

13. _____ What do scientists call the process of carbon dioxide absorbing the heat of the Earth's surface, slowing the escape of heat from the Earth's surface to space?
- a. Wildlife preservation
 - b. Climate Change
 - c. Greenhouse Effect
 - d. Ozone
14. _____ This biome is found in the Northern hemisphere close to the polar region. There is a wide range of temperatures between winter and summer seasons. Winters are long and cold, and the summers are short and cool. Precipitation is moderately high throughout the year with snow occurring during the winter months. Soil is permanently frozen.
- a. Tundra
 - b. Taiga
 - c. Desert
 - d. Tropical Savannah
15. _____ This biome is located between the Polar Regions and the tropics. In this biome, trees shed their leaves each fall. The soil is moist and has moderate nutrient levels.
- a. Arctic Tundra
 - b. Tropical Savannah
 - c. Temperate Deciduous Forest
 - d. Tropical Savannah
16. _____ This resource is an example of a renewable resource that can be regenerated over the course of a few years.
- a. Oil
 - b. Water
 - c. Coal
 - d. Natural Gas
17. _____ This biome is the one in which we live in.
- a. Arctic Tundra
 - b. Tropical Savannah
 - c. Temperate Deciduous Forest
 - d. Tropical Savannah
18. _____ What do scientists call the day to day conditions of Earth's atmosphere?
- a. Climate
 - b. Humidity
 - c. Weather
 - d. Meteorology
19. _____ Which factor does affect climate?
- a. Carrying Capacity
 - b. Limiting factors
 - c. Precipitation
 - d. Population density
20. _____ Which population distribution pattern would describe a groups of maggots feeding on pieces of organic matter at the bottom of a garbage can?
- a. Random
 - b. Clumped
 - c. Even

APPENDIX M

SCIENCE QUIZ: ORGANELLE

1. _____ According to the cell theory, all organisms are made up of one or more cells, cells are the basic units of structure and function, and new cells come from existing cells by . . .
A. Reproduction B. Excretion C. Digestion D. Diffusion
2. _____ Mattias Schleiden, Theodor Schwann, and Rudolf Virchow's investigations led to:
A. Invention of the microscope B. Discovery of DNA C. Cell Theory
3. _____ Which organism is prokaryotic and the least complex?
A. Bacteria B. Daisy C. Tiger D. Human
4. _____ The oldest known life forms have come from this type of cell . . .
A. Trikaryotic B. Eukaryotic C. Animal Cells D. Prokaryotic
5. _____ Organelles allow for . . .
A. Diffusion B. Osmosis C. Reproduction D. Specialization
6. _____ This organelle is responsible for producing the ATP needed for the cell.
A. Nucleus B. Mitochondria C. Chromatin D. Endoplasmic Reticulum
7. _____ This membrane enclosed organelle in plants is responsible for storing toxins, water, pigment, salts, and other contents in the cell.
A. Endoplasmic Reticulum B. RNA C. Vacuole D. Nucleus
8. _____ What is the name of the collection of cells that are similar in structure and function that work together?
A. Tissues B. Organs C. Organ Systems D. Organism
9. _____ A chicken heart is an example of what level of cellular organization?
A. Tissues B. Organs C. Organ Systems D. Organism
10. _____ A tiger is an example of what level of cellular organization?
A. Tissues B. Organs C. Organ Systems D. Organism

Directions: For part II read each poem. Then identify the organelle described by the poem on the line provided below each poem.

1. Identify the organelle described by this poem_____

It is the brain of the operation and control center of all cellular life.
At its center there is precious gold that directs and acts as the hub of cellular activity.
Surrounded by a membrane the DNA is kept safe.
This is the most intelligent part of the cell, keeping everything on track.

-Andrew Rainal

2. Identify the organelle described by this poem_____

I am the power house of the cell
Keeping cells alive and well
Inside of me cristae lie
With ATP its live or die

I help dancers do the hustle
Because there are a lot of me in muscle
Working is what I love to do
Helping the cell to make it through

-David Birmingham

3. Identify the organelle described by this poem_____

I'm at the back of the cell and move back and forth,
I propel the cell to go South or North.
I am a very long strand just like a tail,
but I move all around unlike a rail.
I am the opposite of cilia because I am usually alone,
but I have the power to bring cells home.
My filament helps the sperm cell go really fast,
so that when it is in the fertilization race it does not get passed.
But after the race I don't get a rest,
I keep going on like the heart in your chest!

-Stephen Ferm

4. Identify the organelle described by this poem_____

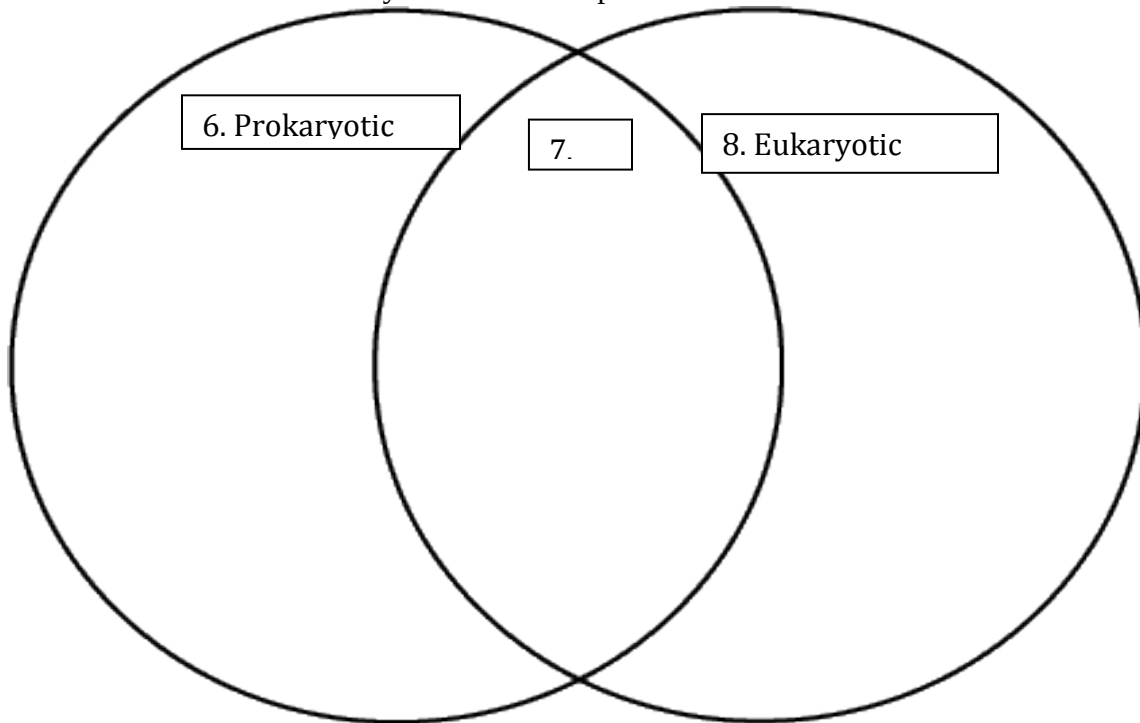
I am the only way out of the cellular city.
 Smooth in some parts and potholes make my organelle surface very pretty.
 My rough parts are abundant with ribosomes galore,
 and my smooth parts contain enzymes that detoxify drugs so they are no more!
 My ribosome's are like crazy speed bumps and generate proteins in long chains and
 chunks!

-Oscar Ponciano

5. Identify the specific organelle described by this poem_____

I transform sunlight energy into chemical energy
 I contain the essential green pigment that everyone wishes they had
 I create the usable organic compounds for glycolysis & respiration
 I am the solar converter of the universe!
 -Erin Colfax

6. – 8. Using the Venn Diagram below, compare and contrast prokaryotic and eukaryotic. In order to receive full credit you will need to place a minimum of 3 facts in each area.



9. Which structures in the cells shown in Figure 7–9 below are responsible for meeting the cells' energy needs? Based on the presence or absence of these structures, identify which cell is a plant cell.

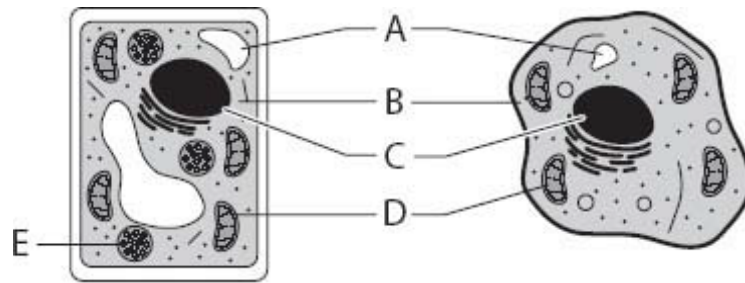


Figure 7–9

10. During the nineteenth century, many scientists and naturalists studied microscopic organisms using magnifying lenses and simple microscopes. After studying plant tissues, animal tissues, and protozoan's under the microscope, scientists summarized their observations of cells and formulated the cell theory. Which would NOT be included as part of the cell theory?

- A. All living things are made of one or more cells.
- B. Cells are the building blocks of living structures.
- C. Parent cells pass genetic material on to daughter cells.
- D. Unicellular organisms can grow from organic molecules.

Explain.

Directions: Extra Credit. Then identify the organelle described by the poem on the line provided below each poem titled: The Cell

1. Like every reception, there's food
2. and dancing and bumping
3. into all those quirky
4. relatives: blood, Great Aunt Henriette
5. says, is thicker than
6. anything, it's in
7. the genes, she says, as if she just
8. discovered the cell,
9. the body's time capsule,
10. recording history for the clumsy, naked
11. bipeds who hover at
12. the edge of fire,
13. evolving into creatures who learn
14. the cells workings:
15. how it sucks up
16. water from the surrounding matrix
17. through sticky-lipped
18. pores; how each tiny
19. apparatus for food or sex floats
20. in this one drop of opaque
21. saline-the primal jelly;
22. how it transcribes proteins from
23. inborn templates for the
24. generations of identical daughters;
25. how it prepares for the wedding, swollen
26. chromosomes unwind, line up,
27. pull to the center and
28. disperse in their Virginia Reel,
29. mitosis: then the cleaving in two,
30. the rift, the birth, transformed.

*. In lines 16-18 in the poem, identify and describe what the poet is referring to?

*. What is the poet referring to when she speaks of the “primal jelly” in line 21 of the poem?

*. Which organelle would be responsible for the actions described in lines 22-24 in the poem?

APPENDIX N

SCIENCE QUIZ: GENETICS

1. ____ The phenotype ratio which results from the crossing two heterozygous organisms for Tongue rolling is:
 A) 1:1:1:1 B) 1: 2: 1 C) 3: 1 D) 1: 1: 2 E) 9: 3: 3: 1
2. ____ In a cross between two tall plants a phenotype ratio of 3:1 is produced. What would be the expected genotypes of the parents?
 A) tt x tt B) TT x TT C) Tt x Tt D) TT x Tt E) tt x TT
3. ____ Which of the following represents, a homozygous recessive set of alleles?
 A) Dd B) DD C) DT D) Dt E) dd
4. ____ Physical characteristics expressed in words are known as:
 A) F1 B) phenotype C) genotype D) P1 E) gene symbols
5. ____ Which of the following genotypes represents an organism that is heterozygous for two traits?
 A) AaBB B) AABb C) AaBb D) AABB E) aabb
6. ____ The person known as the “Father of Genetics” is:
 A) Punnett B) Mendel C) Watson D) Crick E) Leeuwenhoek
7. ____ A cross that involves one trait is called:
 A) dihybrid B) trihybrid C) monohybrid D) tetraploid E) monoploid
8. ____ Hitchhiker’s thumb (H) is dominant over straight thumb (h). A male who is homozygous for hitchhiker’s thumb marries a woman who has a straight thumb. What is male’s genotype?
 A) HH B) H C) h D) hh E) Hh
9. ____ A Garfield cat is an example of what pattern of inheritance?
 A) co-dominant B) multiple alleles C) polygenic inheritance D) incomplete dominance
10. ____ A male who is completely homozygous dominant for roman nose and curly hair has offspring with a female who is completely homozygous recessive for straight nose and straight hair. What is the percentage of the offspring would be expected to have roman nose and straight hair?
 A) 0%, B) 10%, C) 25%, D) 75%, E) 100%
11. ____ The type of inheritance shown when a red-flowering plant is crossed with a white-flowering plant and only pink-flowering plants are produced is:
 A) complete dominance B) incomplete dominance C) polygenic inheritance
12. ____ Cross a male who is hybrid for Roman nose, and has short eyelashes with a female who is homozygous for Roman nose and has short eyelashes. Roman nose (R) is

dominant over straight nose (r). Long eyelashes (L) is dominant over short eyelashes (l). What percentage of the offspring will have Roman nose, short eyelashes?

- A) 0% B) 25% C) 75% D) 100% E) none of these

Directions: the following questions are based around the following genetics problems:

13. Generate a punnett square based on: Curly Hair (H) is dominant over straight hair (h). A man has a genotype of Hh mates with a woman who is hh.

Dimples (D) are dominant over non-dimples (d). Brown eyes (B) are dominant over blue eyes (b). Cross a non-dimpled male who is homozygous for brown eyes with a heterozygous dimpled female who has blue eyes.

_____ 14. Show the genotype of the male

_____ 15. Show the genotype of the female.

_____ 16. Show the gamete type(s) that the male could produce.

_____ 17. Show the gamete type(s) that the female could produce.

18. Show the genotypes and ratios for the possible offspring of this cross.

19. Show the phenotypes and ratios for the possible offspring of this cross.

20. Show your work for this cross.

APPENDIX O

SCIENCE QUIZ: MEIOSIS

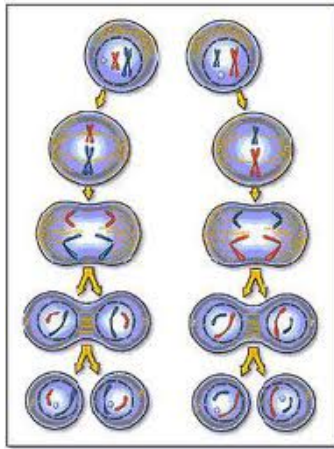
- [illegible]

Directions: The following questions are fill in the blank / short answer. Read the questions thoroughly before proceeding and answering.

11. When human cells undergo meiosis I, they have already prepared for this process by going through, G₁, possibly G₀, S, and G₂. How many chromosomes does the cell that is going to undergo prophase I contain? _____
12. When human cells undergo meiosis II, they have already prepared for this process by going through, meiosis I: Prophase I, Metaphase I, Anaphase I, Telophase I, Cytokinesis I and interkinesis. How many chromosomes do each of the cells that will undergo prophase II contain? _____
13. Crossing over is a process that occurs where information that is contained on one chromatid swaps information with its sister chromatid. In essence they are

exchanging alleles for the same trait, this process occurs in Prophase I. **Why does this occur? What advantage does this process provide to sexually reproducing organisms as compared to asexual reproducing organisms?**

14. **Interpret the meiotic phase being described and explain what will occur in the phase that follows...** homologous chromosome pairs and their sister chromatids prepare for separation. They interact with spindle fibers which form from either side of the nuclear envelope of the cell. The spindle fibers are produced from a structure called a centrosome, composed of a pair of organelles called centrioles. The centrosome replicates and moves to opposite ends of the cell, which is referred to as poles. During this phase the chromosomes are lined by the spindle fibers in the center of the cell.
15. Remember, meiosis is the process utilized to produce sexual gametes in animals. It allows for genetic variation by fusing one half of a zygotes genetic information from its mother (egg) and one half of its father (sperm). Study the diagram below. **In particular, name and describe in detail that final process pictured in the diagram that would take place in males.**



APPENDIX P

SCIENCE QUIZ: PROTEIN SYNTHESIS

- Look at the secret code that involves 4 different simple symbols. Correlate these four different symbols to the processes of transcription, translation, and protein synthesis. What do you think these four symbols represent? $\wedge$ $\vee$ $\subset$ $\cap$
- Look at the original secret code...

$\wedge\vee\subset - \cap\wedge\vee - \subset\wedge\cap - \cap\cap\cap - \subset\wedge\cap - \cap\wedge\vee - \subset\wedge\cap - \vee\subset\cap - \vee\vee\vee - \wedge\wedge\wedge - \subset\subset\subset$

Look at the second version of the secret code...

$\wedge\vee\subset - \cup\wedge\vee - \subset\cup\wedge - \cup\cup\cup - \subset\cup\wedge - \cup\wedge\vee - \subset\wedge\cap - \vee\subset\cup - \vee\vee\vee - \wedge\cup\wedge - \subset\subset\subset$

How is the original secret code different that the second version of the secret code above?

- Look at the secret code again...

$\wedge\vee\subset - \cap\wedge\vee - \subset\wedge\cap - \cap\cap\cap - \subset\wedge\cap - \cap\wedge\vee - \subset\wedge\cap - \vee\subset\cap - \vee\vee\vee - \wedge\wedge\wedge - \subset\subset\subset$

Look at the second version of the secret code again...

$\wedge\vee\subset - \cup\wedge\vee - \subset\cup\wedge - \cup\cup\cup - \subset\cup\wedge - \cup\wedge\vee - \subset\wedge\cap - \vee\subset\cup - \vee\vee\vee - \wedge\cup\wedge - \subset\subset\subset$

Correlate these two different codes to the processes of transcription, translation, and protein synthesis. What do you think these two codes represent? (Be specific)

- Again correlate these two different codes to the processes of transcription, translation, and protein synthesis. Where in the cell would the second code be created?

- Keeping in mind the processes of transcription, translation, and protein synthesis. If the second version of the code is written in 3 symbol segments, what do these three symbol segments represent?

$\wedge\vee\subset - \cup\wedge\vee - \subset\cup\wedge - \cup\cup\cup - \subset\cup\wedge - \cup\wedge\vee - \subset\wedge\cap - \vee\subset\cup - \vee\vee\vee - \wedge\cup\wedge - \subset\subset\subset$

- Using the chart below, you will find that every set of three symbols in the second version of the code found above, correlates to a word. Keeping in mind the processes of transcription, translation, and protein synthesis what molecule would bring in the equivalent of a "word" ?

- Read the second version of the code found above and fill in the chart below...

Symbol Sequence	Coordinating Word	# of times sequence repeats	Symbol Sequence	Coordinating Word	# of times sequence repeats	Symbol Sequence	Coordinating Word	# of times sequence repeats
$\wedge\vee\subset$	purple		$\subset\cup\wedge$	grow		$\subset\subset\subset$	weather	
$\cup\wedge\vee$	flowers		$\cup\cup\cup$	Best		$\cup\wedge\vee$	very	
$\vee\vee\vee$	and		$\vee\subset\cup$	Soil		$\subset\wedge\cap$	acidic	
$\subset\cup\wedge$	in		$\wedge\cup\wedge$	Sunny				

8. Follow the code to create the sentence according to the “word” chart above. Write the sentence below.
9. The creation of the sentence is the equivalent to what molecule within the processes of transcription, translation, and protein synthesis?
10. Words: Sentence :: _____: _____

APPENDIX Q

STUDENT INTERVIEW QUESTIONS

Participation in this research interview is voluntary and participation or non-participation will not affect a student's grades or class standing in any way.

Name: _____

Date: _____

ID #: _____

Period: _____

Gender: _____

Age: _____

Time: _____

Location: _____

1. What are your feelings towards using poetry in science class?
2. Did you find the integration of poetry into the learning process to be distracting?
3. Did you find the integration of poetry to be helpful to your learning / understanding of science concepts? How so?
4. What are your feelings towards writing essays in science class?
5. Did you find that writing the essay helped you to break down the concept into meaningful chunks of information?
6. Did you feel that writing the poem helped you to break down the concept into meaningful chunks of information?
7. Did the poem allow you to better visualize the science concepts? If yes, how so?
8. Did the essay allow you to better visualize the science concepts? If yes, how so?
9. Did you use the rubric to focus your writing of either the poems or the essays? If yes, how so?
10. Did you use the exemplars to guide your writing of either the poems or the essays? If yes, how so and how often?
11. Did you prefer to write an essay or a poem?
12. Did you see any benefit to using descriptive language techniques in science?
13. Can you provide me with a descriptive language technique that you learned through this process?
14. Can you provide me with an example that you created using descriptive language techniques?
15. Do you see yourself using descriptive language techniques in the future in science? If yes, how so and why? If no, why not?

APPENDIX R

RESEARCH PARTICIPANT LETTER II WITH PHOTO RELEASE

**Morristown
High School**

Science Department / Science Academy: 50 Early Street, Morristown, NJ 07960-3898

Hello Biology Honors Parents,

November 29, 2011

As many of us have come to realize over the first marking period, biology is a subject matter that is often difficult for our students to understand because of the multifaceted concepts and technical vocabulary that is deeply rooted in the fundamental ideas that surround the essence of the subject matter. Since September, students in my honors biology classes have been introduced to various descriptive language techniques and routines to help them visualize and connect with the material associated with such concepts. Students have made great strides in grasping the concepts and making biology become more concrete.

Starting in December we will begin to cover some topics that will be completely new to our students. These concepts are often studied in a closed environment where access to experiences can be limited due to available advanced laboratory equipment. These concepts will include cellular biology topics such as the cell cycle, transcription, translation, and DNA replication. I have found that when students do not have an opportunity to physically discover or readily connect with advanced scientific concepts the complexity of the topics being explored increases and true understanding cannot be guaranteed. This lack of accessibility forces a need for a more tangible means to be utilized in order to help learners develop and anchor theoretical constructs. I have found that by using descriptive language techniques such as metaphor, simile, and visual/sensory imagery to illustrate these biological concepts students are able to better visualize and connect with what they are learning. As advanced abstract concepts are revealed students will be introduced to and generating scientific poetry, essays, & literature that incorporates descriptive language techniques to assist in expanding their foundational knowledge of various biological topics. At the conclusion of each conceptual unit, students will be given several different options to choose from in order to display their understanding of select concepts. Additionally, the work of certain students who display a level of content mastery of these advanced biological topics through their science writing may be selected to have their work showcased at the Montana State University Science Education Symposium in July 2012.

So please continue to partner with me on this journey to assist your child in embracing cross-curricular student centered learning that will allow for your child to connect with and develop learning constructs in order to anchor various advanced biological concepts in their mind. If you should desire any further information or background at any point in time, please do not hesitate to contact me by phone (973) 292-2000 ext. 2174 or by e-mail: erin.colfax@morristownhighschool.org

Please sign and return this letter to acknowledge that you have read and received it. There is also a photographic release form on the back.

Thank you,
Erin Colfax Biology Teacher

Parent Signature: _____ Student Name: _____

**Morristown
High School**

Science Department / Science Academy
50 Early Street, Morristown, NJ 07960-3898



Photographic Release Form

If the written work of your child displays a level of content mastery of advanced biological and is selected for showcase at the Montana State University Science Education Symposium in July 2012, Mrs. Colfax will be taking a photograph of your child to accompany their work. Please initial in the spaces below what uses of these photographs you consent to, and sign at the bottom of the release form. Photos will only be used in the ways you consent to.

1. _____ Photographs can be reviewed by Mrs. Colfax.
2. _____ Photographs can be used for science writing illustration.
3. _____ Photographs can be used for academic conference presentations.
4. _____ Photographs can be posted on a web site for academic purposes.

I have read the above descriptions and give my consent for the use of the photographs as indicated by my initials above.

Signature _____

Date: _____

Parent Signature

Signature _____

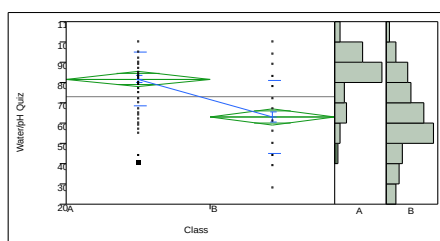
Date: _____

Teacher's Signature

APPENDIX S

PART 1: INDEPENDENT T-TEST RESULTS

One-way Analysis of Water/pH Quiz By Class

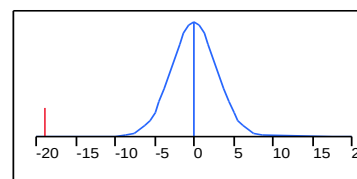


Means and Std Deviations

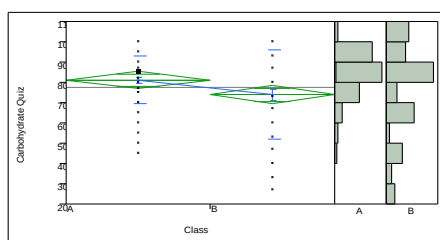
Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
A	67	81.7463	13.0469	1.5939	78.564	84.929
B	58	62.9138	17.9035	2.3508	58.206	67.621

Independent t-Test: B(2010-2011) – A(2011-2012): Assuming unequal variances

Difference	-18.832	t Ratio	-6.63053
Std Err Dif	2.840	DF	102.708
Upper CL Dif	-13.199	Prob > t	<.0001*
Lower CL Dif	-24.466	Prob > t	1.0000
Confidence	0.95	Prob < t	<.0001*



One-way Analysis of Carbohydrate Quiz By Class

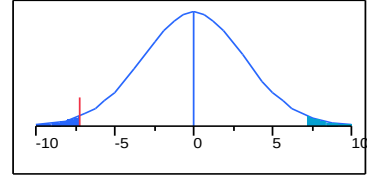
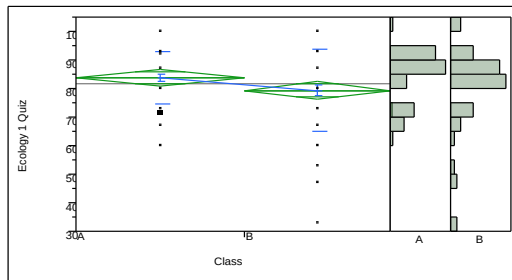


Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
A	67	81.1045	11.7139	1.4311	78.247	83.962
B	58	73.8448	21.9471	2.8818	68.074	79.616

Independent t-Test: B(2010-2011) –A(2011-2012): Assuming unequal variances

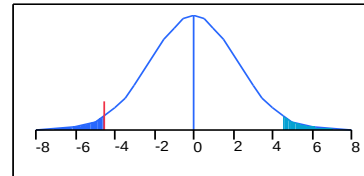
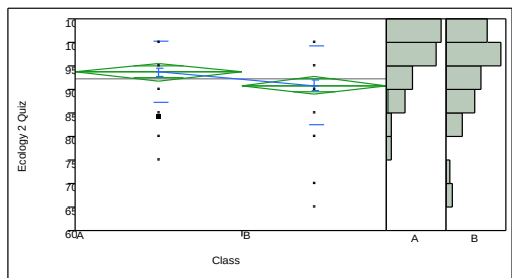
Difference	-7.260	t Ratio	-2.25625
Std Err Dif	3.218	DF	84.15926
Upper CL Dif	-0.861	Prob > t	0.0266*
Lower CL Dif	-13.658	Prob > t	0.9867
Confidence	0.95	Prob < t	0.0133*

**One-way Analysis of Ecology 1 Quiz By Class****Means and Std Deviations**

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
A	67	83.8209	9.1815	1.1217	81.581	86.060
B	58	79.3276	14.3067	1.8786	75.566	83.089

Independent t-Test: B(2010-2011) –A(2011-2012): Assuming unequal variances

Difference	-4.4933	t Ratio	-2.05365
Std Err Dif	2.1880	DF	94.51504
Upper CL Dif	-0.1494	Prob > t	0.0428*
Lower CL Dif	-8.8373	Prob > t	0.9786
Confidence	0.95	Prob < t	0.0214*

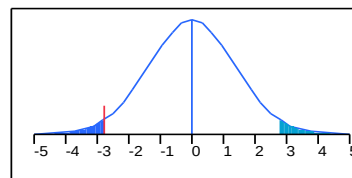
**One-way Analysis of Ecology 2 Quiz By Class****Means and Std Deviations**

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
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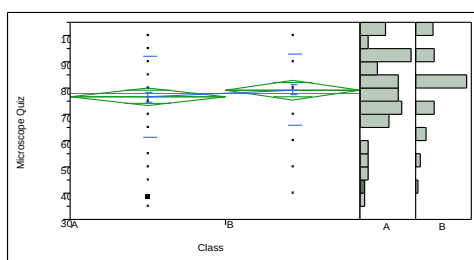
Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
A	67	93.6567	6.48904	0.7928	92.074	95.240
B	58	90.8621	8.43645	1.1078	88.644	93.080

Independent t-Test: B(2010-2011) –A(2011-2012): Assuming unequal variances

Difference	-2.7946	t Ratio	-2.05156
Std Err Dif	1.3622	DF	106.2639
Upper CL Dif	-0.0940	Prob > t	0.0427*
Lower CL Dif	-5.4953	Prob > t	0.9787
Confidence	0.95	Prob < t	0.0213*



One-way Analysis of Microscope Quiz By Class

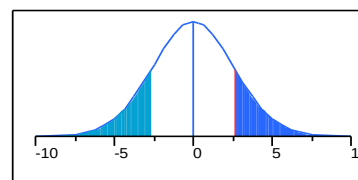


Means and Std Deviations

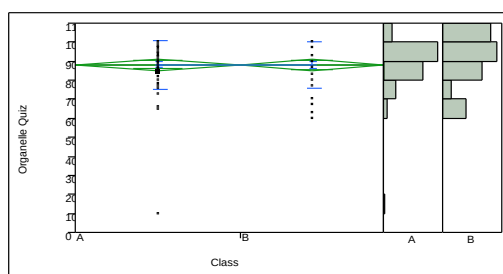
Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
A	67	76.6418	15.2352	1.8613	72.926	80.358
B	58	79.3103	13.4897	1.7713	75.763	82.857

Independent t-Test: B(2010-2011) –A(2011-2012): Assuming unequal variances

Difference	2.6686	t Ratio	1.038591
Std Err Dif	2.5694	DF	122.9309
Upper CL Dif	7.7546	Prob > t	0.3010
Lower CL Dif	-2.4174	Prob > t	0.1505
Confidence	0.95	Prob < t	0.8495



One-way Analysis of Organelle Quiz By Class

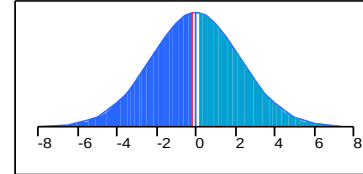
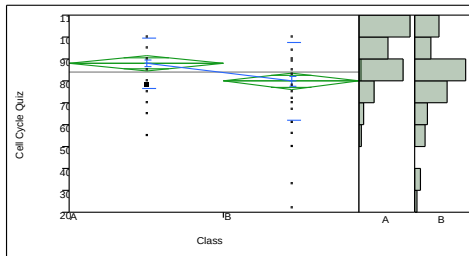


Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
A	67	88.1642	12.8483	1.5697	85.030	91.298
B	58	88.0172	12.1055	1.5895	84.834	91.200

Independent t-Test: B(2010-2011) –A(2011-2012): Assuming unequal variances

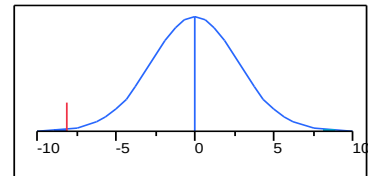
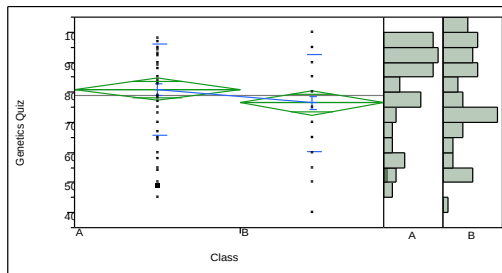
Difference	-0.1469	t Ratio	-0.06578
Std Err Dif	2.2339	DF	122.0975
Upper CL Dif	4.2753	Prob > t	0.9477
Lower CL Dif	-4.5692	Prob > t	0.5262
Confidence	0.95	Prob < t	0.4738

**One-way Analysis of Cell Cycle Quiz By Class****Means and Std Deviations**

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
A	66	87.9545	11.6347	1.4321	85.094	90.815
B	58	79.8103	17.9125	2.3520	75.100	84.520

Independent t-Test: B(2010-2011) –A(2011-2012): Assuming unequal variances

Difference	-8.144	t Ratio	-2.95751
Std Err Dif	2.754	DF	95.57973
Upper CL Dif	-2.678	Prob > t	0.0039*
Lower CL Dif	-13.611	Prob > t	0.9980
Confidence	0.95	Prob < t	0.0020*

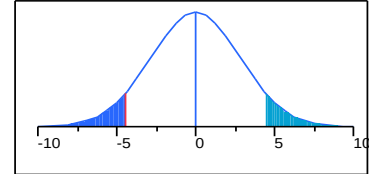
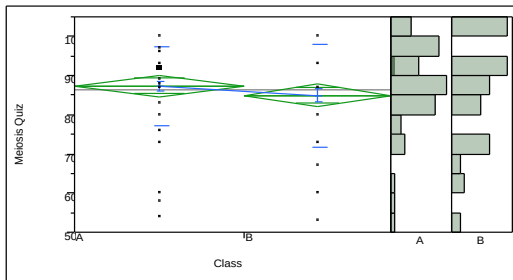
**One-way Analysis of Genetics Quiz By Class**

Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
A	67	81.0000	15.2445	1.8624	77.282	84.718
B	58	76.5517	16.1193	2.1166	72.313	80.790

Independent t-Test: B(2010-2011) – A(2011-2012): Assuming unequal variances

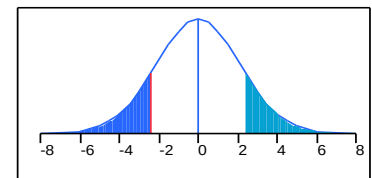
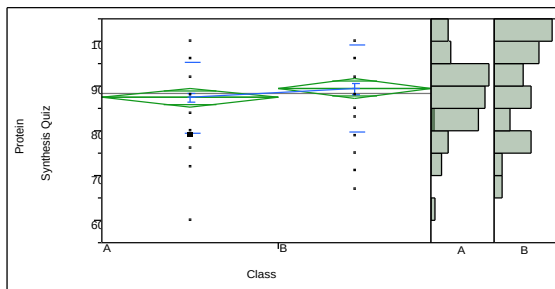
Difference	-4.448	t Ratio	-1.5778
Std Err Dif	2.819	DF	118.2264
Upper CL Dif	1.135	Prob > t	0.1173
Lower CL Dif	-10.031	Prob > t	0.9414
Confidence	0.95	Prob < t	0.0586

**One-way Analysis of Meiosis Quiz By Class****Means and Std Deviations**

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
A	67	87.3582	10.0419	1.2268	84.909	89.808
B	58	84.9828	13.1356	1.7248	81.529	88.437

Independent t-Test: B(2010-2011) – A(2011-2012): Assuming unequal variances

Difference	-2.3755	t Ratio	-1.1223
Std Err Dif	2.1166	DF	105.8633
Upper CL Dif	1.8210	Prob > t	0.2643
Lower CL Dif	-6.5719	Prob > t	0.8679
Confidence	0.95	Prob < t	0.1321

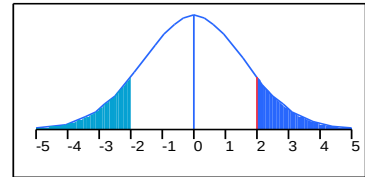
**One-way Analysis of Protein Synthesis Quiz By Class**

Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
A	67	87.4030	7.91634	0.9671	85.472	89.334
B	58	89.3966	9.79248	1.2858	86.822	91.971

Independent t-Test: B(2010-2011) – A(2011-2012): Assuming unequal variances

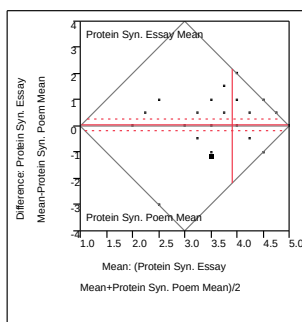
Difference	1.9936	t Ratio	1.23906
Std Err Dif	1.6089	DF	109.4767
Upper CL Dif	5.1823	Prob > t	0.2180
Lower CL Dif	-1.1951	Prob > t	0.1090
Confidence	0.95	Prob < t	0.8910



APPENDIX T

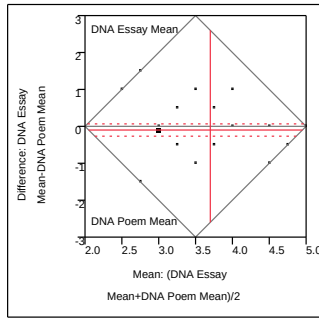
PART 2: SUMMARY /GRAPHS OF THE DEPENDENT T-TEST (MATCHED PAIRS)

Matched Pairs: Protein Synthesis Essay Mean vs. Protein Synthesis Poem Mean



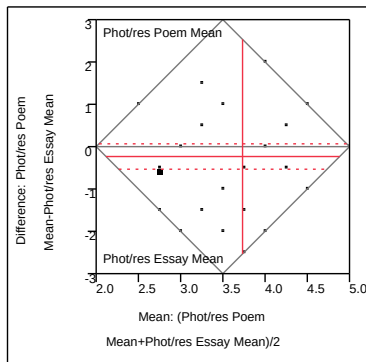
Protein Syn. Essay Mean	3.94118	t-Ratio	0.330409
Protein Syn. Poem Mean	3.90196	DF	50
Mean Difference	0.03922	Prob > t	0.7425
Std Error	0.11869	Prob > t	0.3712
Upper 95%	0.27761	Prob < t	0.6288
Lower 95%	-0.1992		
N	51		
Correlation	0.5611		

Matched Pairs: DNA Essay Mean vs. DNA Poem Mean



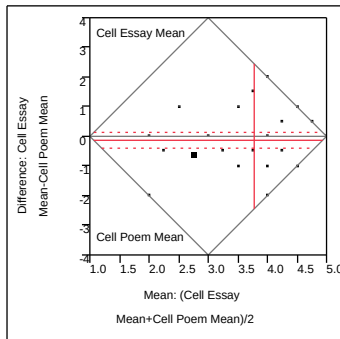
DNA Essay Mean	3.64706	t-Ratio	-1.10675
DNA Poem Mean	3.7451	DF	50
Mean Difference	-0.098	Prob > t	0.2737
Std Error	0.08858	Prob > t	0.8632
Upper 95%	0.07989	Prob < t	0.1368
Lower 95%	-0.276		
N	51		
Correlation	0.58031		

Matched Pairs: Photosynthesis /respiration Poem Mean vs. Photosynthesis /respiration Essay Mean



Phot/res Poem Mean	3.62	t-Ratio	-1.60738
Phot/res Essay Mean	3.86	DF	49
Mean Difference	-0.24	Prob > t	0.1144
Std Error	0.14931	Prob > t	0.9428
Upper 95%	0.06005	Prob < t	0.0572
Lower 95%	-0.5401		
N	51		
Correlation	0.1021		

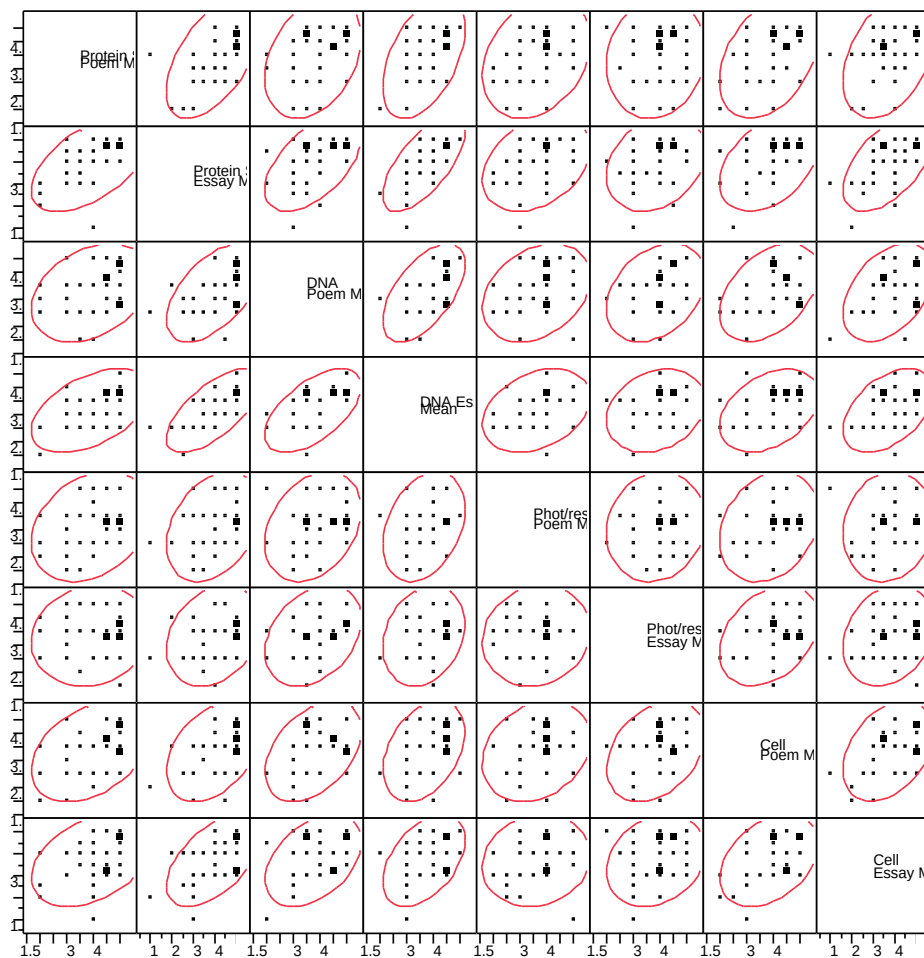
Matched Pairs: Cell Essay Mean vs. Cell Poem Mean



Cell Essay Mean	3.71	t-Ratio	-1.15079
Cell Poem Mean	3.86	DF	49
Mean Difference	-0.15	Prob > t	0.2554
Std Error	0.13034	Prob > t	0.8723
Upper 95%	0.11194	Prob < t	0.1277
Lower 95%	-0.4119		
N	51		
Correlation	0.34831		

APPENDIX U

PART 2: DATA AND ANALYSIS SCATTERPLOT MATRIX



Key:

Cell Poem Mean = Cell Poetry Mean Score

Cell Essay Mean = Cell Essay Mean Score

Phot/res. Poem Mean = Photosynthesis/respiration Mean Poetry Score

Phot/res. Essay Mean = Photosynthesis/respiration Mean Essay Score

DNA Poem Mean = DNA Poem Mean Score

DNA Essay Mean = DNA Essay Mean Score

Protein Syn. Poetry Mean = Protein Synthesis Poetry Mean Score

Protein Syn. Essay Mean = Protein Synthesis Essay Mean Score

(The correlations are estimated by REML method)

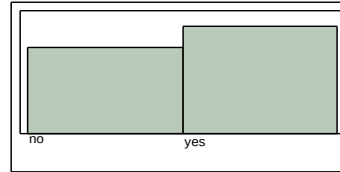
APPENDIX V

PART 2: DATA AND ANALYSIS DISTRIBUTION TABLES / GRAPHS

Chunking vs. Visualizing Poetry/Essays

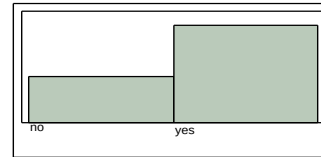
Distribution: Chunking poetry Frequencies

Level	Count	Probabilities
no	21	0.44681
yes	26	0.55319
Total	47	1.00000



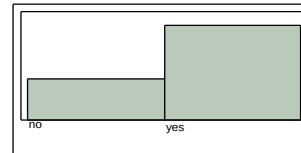
Distribution: Chunking essay Frequencies

Level	Count	Probabilities
no	15	0.31915
yes	32	0.68085
Total	47	1.00000



Distribution: Poetry Visual Frequencies

Level	Count	Probabilities
no	14	0.29787
yes	33	0.70213
Total	47	1.00000



Distribution: Essay Visual Frequencies

Level	Count	Probabilities
no	20	0.42553
yes	27	0.57447
Total	47	1.00000

