

Science and Mathematics Education Centre

**Student Understanding, Attitude and Achievement: Assessment
Comparisons in Genetics and Photosynthesis/Respiration**

Serena McCalla

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DECLARATION

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university. To the best of my knowledge and belief, this thesis contains no material previously published by any person except where due acknowledgment has been made.

A handwritten signature in cursive script, reading "Serena McCall", is written above a horizontal line.

Date: January 2014

ABSTRACT

Research evidence and student performance in science courses in New York State after graduating from high school suggests that there is a distinct difference between a students' ability to memorize given areas of study versus the ability to understand coursework which is presented to them. Many students have been taught to memorize definitions, formulas, and historical facts as the mode of learning in science class. This in turn has not enabled higher levels of understanding in the sciences. This study compares a range of assessment tools to ascertain students' understanding, attitude and achievement in two-selected science domains: photosynthesis/respiration and genetics as impacted by constructivist teaching. Administration of standardized questions from past New York State Regents examinations and released Advanced Placement Biology items, followed by administration of two-tier multiple choice diagnostic examinations, and cumulative New York State Living Environment Regents examinations were used to identify advanced student competence in the previously stated topics. Consequently, the study focused on students' ability to attain understanding of these two topics by way of constructivist teaching methods and assessment of learning through concept maps and student interviews. Student interviews and changes in teaching strategies provided valuable information towards the effectiveness of standardized tests as a means to measure understanding of two topics taught in the NYS Living Environment curriculum. Students' attitudes towards science (via TOSRA) and constructivist teaching modalities were triangulated with outcomes of all achievement measures including standardized tests using past New York State Regents examinations and released AP Biology items, two-tier multiple choice diagnostic examinations, and the New York State Living Environment Regents examinations. This study concluded the Living Environment Regents examination was not an adequate measure of advanced student understanding of photosynthesis/respiration and genetics when triangulated against student opinion, attitude outcomes, and scores on the two-tier diagnostic examinations.

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Chapter 1

INTRODUCTION

1.1 Overview of Chapter and Introduction to Study

This chapter provides the background upon which this study was developed and implemented. The research problems (Section 1.2) for the study are presented, followed by the study context (Section 1.3), the rationale and theoretical orientation of the study (Section 1.4), the research questions (Section 1.5), the research design (Section 1.6), and the tools used to explore constructivist teaching methods (Section 1.7). The instruments used to measure student attitudes towards science (Section 1.8) are followed by the significance of the goals of the study (Section 1.9) and an outline of the limitations (Section 1.10). The chapter concludes with an overview of the thesis (Section 1.11).

1.2 Research Problems

This study addresses the breach between current testing measures (standardized, end of year, New York State mandated examinations compared to two-tier multiple choice diagnostic examinations) and assessment of student knowledge and understanding in two high school science topics identified in the New York State (NYS) Living Environment (LE) curriculum – Genetics and Photosynthesis/Respiration. This study investigated whether or not there were any shortcomings of the NYS Living Environment Regents Examination as an accurate measure of student understanding. During this investigation, the development of teaching strategies which fostered student learning using constructivist teaching practices, analysis of student attitudes towards learning, use of diagnostic examinations to compare outcomes with standardized examinations and qualitative analysis of test items to ascertain student learning were examined.

1.3 General Study Context

Students in New York State, as of June 2012, are required to pass (score of 65 or better) one state level examination in science to graduate from High School with a Regents Diploma or pass two examinations (one physical and one life science) for a Regents Diploma with Advanced Designation in lieu of a local diploma. The two examinations most associated with fulfilling this requirement are the Living Environment (life science) and the Physical Setting/Earth Science Regents (NYSESED, 2008). Being the recipient a Regents Diploma supersedes the local diploma when viewed for admission to colleges and most other institutions of higher learning (NYSL, 2013).

New York State's (NYS) Learning Standards are used by school personnel to identify major education goals that guide students' learning and teachers' curriculum development, including the understanding of skills and concepts taught in high school science classrooms. The purpose of the Regents Examinations is to evaluate both the quality of instruction and the learning achieved after subsequent implementation of the Learning Standards for each discipline of science (NYSESED, 2007). The goals of all are to have students score well on these examinations, yet this goal may not be achieved without an understanding of the core curricula such as genetics and photosynthesis/respiration concepts. The multiple choice sections of the NYS Regents Examinations are very similar in content each year therefore repeated practice of previous examinations and drilling of facts may adequately prepare students to score well upon examination.

The No Child Left Behind Act of 2001 supports the idea of increasing academic standards and the implementation of challenging curricula in order to attain higher levels of achievement for all students. However, the goal of this act is difficult to ascertain with the influx of students into already overcrowded classrooms and increased numbers of second language learners; even so measures have been implemented to determine success of scholastic programs in the high school. The proposed goal of the NYS Living Environment Regents Examination, as a standardized test, is to assess student learning and determine the standard of success of these American students in learning the work in which they have been engaged.

Both the goals of the No Child Left Behind Act and the New York State Education Department are to provide valid and reliable assessments to determine student achievement, yet the examinations associated with this achievement may not directly assess learning or understanding of concepts. Examinations should be devised to test how well a student understands a given concept.

Assessments should provide an accurate and reliable measure of students' achievement. Reliability plays a role because the assessments must be able to precisely and consistently measure students' understanding and knowledge for each item placed on the standardized examinations. This demand has created many interesting dilemmas for the secondary science/high school teacher. Bishop et al. (2000), Furtak (2006), Gallagher (1996), and Glass (2013) present the dilemma associated with high school science teachers' goals of completing a given syllabus in the time allotted (the school calendar year) with appropriate assessment. This allocated timeframe often means that the teacher covers the content without encouraging student understanding. Indeed, the educational system has devised methods for making sure teachers cover content, but limitations exist on how teachers can complete the syllabus while ensuring student understanding (Furtak, 2006; Glass, 2013). Biology, the science from which the Living Environment Core Curriculum was designed, is a difficult science to learn and teach (Sesli & Kara, 2012). Biology is not well structured, is highly complex, and interconnects numerous sub-topics of the living and non-living world (Wandersee, Fisher, & Moody, 2000). Educators not only have to deal with the difficulties of the expanse of the topic, but also the misconceptions their students bring to the classroom. Students' misconceptions prior to entering the classroom originate from family, previous teachings, culture, and observations that are usually not negated by accurate formal instruction (Duit & Treagust, 2003; Lin, 2004; Treagust, 1988).

Diagnostic tests may be used as tools to help teachers begin to remedy misconceptions and better assess student understanding (Haslam & Treagust, 1987). Two-tier diagnostic tests as proposed by several science educators can identify conceptual learning difficulties and may be a better way to assess and diagnose students' alternative conceptions or misconceptions, leading to increased

understanding and a better assessment of students' learning (Haslam, & Treagust, 1987; Lin, 2004; Treagust, 1988; Tsai & Chou, 2002).

The U.S. government, school administrators, educators, parents, and students are interested in understanding how various factors influence students' success. Consequently, it is an essential and inevitable choice to examine the attitude of students regarding those things, which influence them throughout their high school years. In order to assess factors which may influence learning, student interviews and an attitudes towards science test (TOSRA - *Test of Science Related Attitudes*) will be employed as the assessment tool for determining relationships between the high school science students' attitudes, their achievement on statewide examinations and their participation in the learning environment.

1.4 Rationale and Theoretical Orientation

In 1999, former President George W. Bush stated a goal of the American Education Strategy for 2000 would be to increase the United States global ranking in mathematics and science to #1. Nearly two and half decades later the U.S. is still ranked 17th in science and 25th in mathematics as noted in a recently published Harvard University Program on Education Policy and Governance report (U.S. Students Still Lag, 2012). Numerous theories exist to explain why the U.S. ranking in these disciplines has failed to increase, yet the majority of assessment practices have not sufficiently changed to stress skills processing, theoretical understanding, and application of learned terms in science courses. Concurrently, pressures associated with elementary, middle and high school graduation exit examinations have increased over the past two decades (Jacob, 2001).

Specific topics within the NYS Living Environment curriculum require higher-level (critical) thinking skills, such as learning genetics and photosynthesis/respiration. In NYS, teaching and testing complex topics requires cognitively active study behaviors and less rote memorization (Stanger-Hall, 2012) yet these tasks may seem daunting under rigid curricula constraints and limited teacher training (Sandholtz, & Ringstaff, 2013). Currently, no studies on high school science teaching practices aligned with assessment of student understanding using the NYS Living Environment Regents

Examination have been encountered in the literature. Therefore, there is a need for more research in this area.

Assessments of understanding using multiple-choice (MC) questions pose extreme difficulty because these items are associated with rote memorization and not the critical thinking skills associated with comprehension; specifically if multiple choice items are not accompanied by graphical or tabular data or pictorial scenarios, in which students have to read, deduce, infer etc. to derive an answer. Also, using MC questions, understanding might be assumed by the appearance of correct answers upon examination. A probable false indication of student understanding and knowledge may occur during accurate student questions providing answers as a result of guessing. In contrast, constructed response (CR) questions (short answer, essay, graphs, or fill in the blanks) can assess a wider range of thinking skills (Scouller, 1998). The NYS Board of Regents has tried to assess student depth of understanding with the use of CR questions. Currently, however, there are concerns that the evaluation of free response or CR questions on the New York State examinations are completed in a biased manner and the student responses inevitably require more time for grading (Stanger-Hall, 2012). Teachers may be tired while marking papers or may use their own misconceptions to analyze and grade free responses written by students. In contrast, an examination choice not currently used by NYS includes two-tier multiple choice diagnostic items. These examinations are efficient and straightforward allowing students and educators to determine scientifically correct as well as incorrect ideas and the reasoning for associated misunderstandings or misconceptions without bias or grading difficulties (Tsai & Chou, 2002). In this study, two-tier multiple choice diagnostic examinations were used as formative assessments in six advanced secondary science Living Environment classes. The diagnostic assessment also served as a stimulus for students to achieve at a higher level on Regents' examinations and to employ a greater appreciation of the biological sciences through enhanced understanding of two topics, genetics and photosynthesis/respiration.

Teaching style directly influences the learning environment and student understanding; therefore, how teachers teach and assess learning are definitive factors in the learning process. Traditional teachers may show hesitation with

departing from the prescribed curriculum as outlined in course textbooks (Sandholtz & Ringstaff, 2013) and the NYS Learning Standards curriculum guides due to time constraints and self-efficacy associated with deviating from previous instructional practices. Constructivist teaching styles compared to traditional teaching methodologies have been on the forefront of education experts' agenda in order to determine the techniques needed to help students understand various concepts in science at a deeper level (Chiappetta & Koballa, 2006; Duit & Confrey 1996; White, 1998). Issues identified in the literature include teachers not being sensitive to students' existing conceptions, ideas and prejudices; interpreting students' answers/responses in a way that is contrary to the actual students' own idea; and teaching that does not challenge higher cognitive levels of learning (Driver & Scott, 1996; Duit & Confrey, 1996; Chiappetta & Koballa, 2006). Research recommends that the constructivist teacher should identify previous knowledge and establish relationships between concepts taught and propositional knowledge (see for example, Duit & Treagust, 2003). Hence the constructivist-informed teacher should incorporate the use of various learning tools such as concept maps, interactive web sites, free response homework assignments and laboratory activities to encourage a deeper level of student understanding. A recommendation from the literature that needs further support from empirical studies is that students in classes of constructivist-informed teachers can achieve higher scores on diagnostic tools and have a better understanding of the concepts presented within secondary science (Gallagher, 1996; Haslam & Treagust, 1987; Stanger-Hall, 2012).

Constructivist teaching practices coupled with diagnostic testing may serve as a more appropriate measure of student knowledge and increased erudition. Overall, if teachers are able to assist in student learning of science topics in meaningful ways, student understanding of complex topics and identification of alternative conceptions can be addressed through questions on diagnostic examinations without teacher bias or lengthy review of students' assignments.

To conclude this section, it should be noted that in addition this study is groundbreaking for several reasons. First, numerous studies have used a variety of methods to suggest why students have inherent difficulties and alternative conceptions about photosynthesis (and respiration) and genetics but none have incorporated multiple

methods and techniques in a single project as a means to assess and compare achievement. Research shows a variety of nomothetic and idiographic methods to assess and quantify student alternative conceptions and misconceptions over the last few decades. Wandersee (1983) and Eisen and Stavy (1998) used surveys and multiple choice items to reveal students' alternative conceptions about photosynthesis; Hazel and Prosser (1994) used concept maps and traditional examinations to discern misconceptions of students. In other studies, Smith and Anderson (1984) reviewed a teacher case study which manipulated various classroom techniques to deconstruct naïve conceptions students possessed about photosynthesis, and Griffard and Wandersee (2001) triangulated interviews about alternative conceptions in photosynthesis learning as a means to measure validity of conceptual understanding via diagnostic testing. Yaroch (1991) used multiple choice responses with essay questions on genetics and photosynthesis/respiration to diagnosis alternative conceptions, and Treagust and Haslam (1986, 1987), and Adams and Wieman (2010) used interviews to design instruments for diagnostic assessment of alternative conceptions in secondary school student populations.

1.5 Research Questions

This study investigated the impact of a constructivist-informed approach to teaching a Grade-9/10 Regents, advanced/gifted, high school science Living Environment course. The study was designed to evaluate correlations between student understandings, attitudes and test scores when measured by two-tiered multiple choice diagnostic tests, past-standardized test questions and the New York State (NYS) Living Environment Regents examination (specifically questions on genetics and photosynthesis/respiration) as a means to best assess understanding, attitude and achievement of core science curricula in NYS Living Environment courses for advanced secondary male and female students over two years. The initial ideas for creating a project that investigated the impact of a constructivist-informed approach to teaching a Grade 9/10 Living Environment Regents advanced course which encouraged student understanding was based around the idea that, as a teacher of the Living Environment course, I noted that the NYS Living Environments Regents does not test understanding but instead reading comprehension and may hinder success of higher thinking students overall examination scores. The No Child Left Behind Act

and the New York State Education Department assumption that an accurate measure of increased academic standards and consequential alterations of curricula is best accomplished with an increase of students' standardized Regents test taking and increased testing scores deems worthy of further review.

The researcher ascertains that a measure of gifted student understanding and the divisive measure of curriculum understanding is not accurately considered using the current New York State Living Environment Regents Examination as an end of year assessment for advanced/gifted student understanding of challenging core curricula (Herte, 2007). Gifted students may ascertain that the questions and answers as elicited on NYS Living Environment examinations are too generalized to deduce accurate choices for items presented. Many studies have reviewed assessment types for lower achieving students yet none has assessed the opposite effects on gifted students (Day & Matthews, 2008). A true measure of student understanding must come from quantitative and qualitative analyses to determine the significance of students' responses to reflect their understanding of the taught curricula. The following research questions were addressed in this two year study and are organized under three headings - Descriptive and inferential statistics for all tests, Correlations between variables, and Qualitative and Quantitative Data Triangulation (Table 1.1):

Table 1.1: Constructs of research questions and data analysis.

Research Questions	Constructs/Variables Addressed	Types of Data	Analysis Methods
#1 Attitude: <i>How do student attitudes correlate with scoring on assessments in photosynthesis/respiration and genetics and gender?</i>	Student attitudes towards science and observing possible correlates in achievement scores.	1. Quantitative 2. Descriptive Statistics 3. Inferential Statistics	1. Cronbach alpha reliability and mean correlations of TOSRA responses with correlations. 2. Comparing gender with Cronbach alpha reliability and mean correlations of TOSRA responses. 3. Cronbach alpha reliability and mean correlations of all assessment measures using student responses.
#2 Understanding: <i>How does advanced student understanding of photosynthesis/respiration and genetics correlate with gender of students and scoring on assessments?</i>	Student understanding of photosynthesis/respiration and genetics and gender learning. Student understanding of photosynthesis/respiration and genetics as a correlate of achievement scores.	1. Quantitative 2. Descriptive Statistics for correlation of variables	1. Correlations between gender and understanding using outcomes on all assessments. 2. Correlation assessments between first and second tier responses of diagnostic examinations to assess understanding.
#3 Achievement: <i>How does assessment type, student understanding, and student attitudes correlate with achievement scores on standardized multiple choice examinations, two-tier diagnostic examinations, concept maps, and the NYS Living Environment Regents after a course of constructivist teachings?</i>	Student achievement based upon assessment type-quantitative (standardized multiple choice, concept maps, two-tier diagnostic, and the NYS Living Environment Regents), and qualitative (student interviews) as measures of student understanding.	1. Qualitative analysis of learning & achievement 2. Qualitative analysis of learning & achievement via student interviews 3. Data triangulation	1. Scoring concept maps as a measure of understanding and achievement success. 2. Comparing student commentary with quantitative achievement outcomes post constructivist teaching. 3. Comparing pre and post TOSRA, understanding as perceived by students and performance scores on all achievement examinations.

Descriptive and inferential statistics for all tests

Research Question#1: *How do student attitudes correlate with scoring on standardized multiple choice examinations, two-tier diagnostic examinations, concept maps, and the NYS Living Environment Regents in photosynthesis/respiration and genetics?*

- 1a. What are the Cronbach alpha reliability measures and the mean correlations with other scales for the *Test of Science Related Attitudes*?
- 1b. What is the correlation between student responses on pre- and post-tests of the *Test of Science Related Attitudes*?
- 1c. Are there any differences between pre-and post-tests for all students on the *Test of Science Related Attitudes* (TOSRA), Year 1 & Year 2?

- 1d. Are there any differences between pre- and post-tests responses for males and females on the *Test of Science Related Attitudes*, Year 1 & Year 2?
- 1e. What are the Cronbach alpha reliability measures and the mean correlations with past-standardized multiple choice examinations, the two-tier diagnostic examinations and the Living Environment Regents examination in photosynthesis/respiration and genetics, Year 1 & Year 2, respectively?
- 1f. How do student responses compare on past-standardized multiple choice examinations, the two-tier diagnostic examinations and the Living Environment Regents examination in photosynthesis/respiration and genetics, Year 1 & Year 2, respectively?

Correlations between variables

Research Question#2: *How does advanced student understanding of photosynthesis/respiration and genetics correlate with gender of students and scoring on standardized multiple choice examinations, two-tier diagnostic examinations, concept maps, and the NYS Living Environment Regents?*

- 2a. What is the correlation between gender and total assessment outcomes and understandings of photosynthesis and respiration and genetics on past-standardized multiple choice examinations, the two-tier diagnostic examinations, concept maps and the NYS Living Environment Regents (Year 1)?
- 2b. What is the correlation between gender total assessment outcomes understandings of photosynthesis and respiration and genetics on past-standardized multiple choice examinations, the two-tier diagnostic examinations, concept maps and the NYS Living Environment Regents (Year 2)?
- 2c. Does a correlation exists between first tier and second tier responses on the diagnostic examinations in photosynthesis/ respiration (Year 1 and Year 2)?
- 2d. Does a correlation exists between first tier and second tier responses on the diagnostic examinations in genetics (Year 1 and Year2)?

Qualitative and Quantitative Data Triangulation

Research Question#3: *How does assessment type, student understanding, and student attitudes correlate with achievement scores on standardized multiple choice examinations, two-tier diagnostic examinations, concept maps, and the NYS Living Environment Regents after a course of constructivist teachings?*

- 3a. How do concept maps assist in student learning in a constructivist classroom?
- 3b. How do students socially construct understandings in light of positivist, quantitative research in the constructivist classroom and post testing?
- 3c. Which learning instrument do students perceive best assists in their understanding of photosynthesis/ respiration and genetics?
- 3d. Which measure do students perceive best measures their level of understanding of photosynthesis/ respiration and genetics?
- 3e. What is the correlation between students' attitudes towards science, post instruction and their understanding of photosynthesis/respiration and genetics via interviews and assessment responses concept maps interviews in an advanced secondary science living environment course?
- 3f. What is the correlation between student achievement on past-standardized multiple choice examinations, the two-tier diagnostic examinations, concept maps and the Living Environment Regents examination and their understanding of photosynthesis/respiration and genetics in an advanced secondary science living environment course?
- 3g. What is the correlation between student achievement on past-standardized multiple choice examinations, the two-tier diagnostic examinations, concept maps and the Living Environment Regents examination in photosynthesis/respiration and genetics, when compared to student responses on the *Test of Science Related Attitudes* pre- and post-tests and student interviews in an advanced secondary science living environment course?

1.6 Research Design

As a means to address the study purpose, to identify if the NYS Living Environment Regents Examination can measure achievement of advanced students high school science students and serve as a gauge of understanding when compared against two-tier diagnostic examinations, this study used pretest—posttest design repeated over

two years with students in one school (Cohen, Manion & Morrison, 2000). In addition, this work identified the role of constructivist teaching practices to support learning for advanced Living Environment students and if student attitudes towards science changed over a course of instruction.

Qualitative data in the form of interviews were used to report student respondents' opinions of teaching techniques, assessments (concept maps, free-response questions, homework assignments); achievement examinations (past-standardized tests, two-tier multiple choice diagnostic examinations and NYS Regents) were used to measure understanding. Pre-prescribed interview questions with room for probing were used to confirm or reject quantitative data (Kelley et al., 2003). Qualitative data may help establish differences between achievement scores and student attitudes towards science or teaching techniques compared to content activities associated with achievement examinations such as the Living Environment Regents (Oliver-Hoyo & Allen, 2006).

Quantitative data in the form of past-standardized Living Environment and AP Biology test questions in photosynthesis/respiration and genetics were analyzed against the two-tier multiple choice diagnostic examinations, final concept maps, and the Living Environment Regents performances to determine if the scores that students received in the achievement measures actually assessed student learning within the guise of the test structure and goals. The examinations showing the greatest achievement score outcomes should correlate with student perceptions of achievement after testing.

The qualitative data and quantitative data collected in this study should represent a more exacting measure of advanced student learning and achievement in New York State after a course of instruction.

1.7 Constructivist Practices and Assessment Measures

The topics covered in this study were photosynthesis/respiration and genetics, which were based upon New York State Living Environment (learning standards) syllabi (NYSED, 2008). The photosynthesis/respiration unit was completed in three weeks,

while the genetics unit was completed in four weeks for both Year 1 and Year 2 classes. Topics such as genetics, respiration, and photosynthesis especially with the inclusion of new vocabulary and increasing complexity of concept organization can be conceptually difficult for students; therefore several constructivist-informed teaching methods were used in this study (Tsui & Treagust, 2004).

The teacher used constructivist-informed teaching activities that included hands-on activities, open forum discussions, written and essay format homework assignments, reports, projects, computer searches, movies, data analysis, and student interpretation as a means to broaden and decipher students' previous knowledge for construction and deconstruction, the understanding of students learning in the advanced Living Environment high school science classroom and to identify student understanding of science concepts during the course of instruction. Previous studies support students exhibiting varying degrees of understanding, especially with concepts that are difficult to teach and learn (Tsui & Treagust, 2004). Concept maps, interviews, and free response type questions are defined methods to explore student misconceptions or alternative conceptions in science, coupled with the use of diagnostic two-tier examinations (Tsai & Chou, 2002).

Data were collected using standardized items from previous New York Regents Living Environment Examinations (circa 1986-2005) and existing and modified two-tier genetics and photosynthesis/respiration diagnostic tests (Haslam & Treagust, 1987; Tsui & Treagust, 2010) that were identified to cover similar propositional statements that reflected the Living Environment course being taught. Items included precedent items in genetics (95 items), photosynthesis/respiration (80 items) consisting entirely of multiple choice questions over two years. Two-tier diagnostic tests in genetics (15 items) and photosynthesis/respiration (14 items) were designed as two multiple choice parts with the first-tier mainly a statement of fact followed by the second tier comprising reasons for answers chosen in the first tier. The items were sourced from Haslam and Treagust (1987) and Tsui and Treagust (2004) together with items created by the teacher researcher, as a reliable and valid means to assess and improve students' learning of biology.

Generally, several types of tests are used to examine students' academic understanding: classroom tests, state examinations and diagnostic tests. The instruments of specific focus in this study included two-tier diagnostic examinations in the topics of photosynthesis and respiration and genetics, previously administered NYS standardized practice examination items which directly correlated to the format and style of the statewide end of year culminating exam- The New York State Living Environment Regents examination. State examinations are devised to test how well a student understands a given concept and provide an accurate and reliable measure of students' achievement. On the other hand, diagnostic tests can be used to assess and diagnose students' alternative conceptions or misconceptions, leading to increased academic standards (Haslam & Treagust, 1987; Peterson, Treagust, & Garnett, 1989; Treagust, 1988; Tsai & Chou, 2002). A well-designed two-tier diagnostic test can provide a detailed view of assessing students' knowledge prior to and after a course of instruction (Chandrasegaran et al., 2007; Tsui & Treagust, 2010). Concept maps were also used as a means to cultivate constructivist teaching practices and student interviews were used to ascertain qualitative feedback.

To assess students' understandings in this study, data from two years of diagnostic two-tier examinations and the level of understanding realized and measured by standardized examinations assessments from previous Regents Examinations after students had been taught concepts outlined in the Living Environment genetics and photosynthesis/respiration learning standards guide of New York State in six advanced high school Living Environment courses. Implementation of assessments occurred at the end of a course of study of either topic in both years. Students were tested using past standardized Regents examination questions scored in photosynthesis/respiration and genetics, followed by use of previously validated two-tier multiple choice diagnostic questions (Treagust, 1995) including new items which addressed current study student misconceptions. The scores of each achievement examination, for each topic respectively, were evaluated following a three-day review period. A final correlation was assessed with the NYS Regents Examination scores for 163 advanced Living Environment students.

1.8 TOSRA (Test of Science Related Attitude) and Interviews

In order to answer the research questions as outlined in Section 1.5, this study involved the collection of both quantitative and qualitative data. The TOSRA (Test of Science Related Attitude) was used to establish a basis of student perspectives of the science classroom pre and post instruction in a constructivist classroom, along with several instruments (for example, online resources, classroom laboratory exercises and cooperative learning groups) to assess student understanding.

Students were interviewed about their perceptions of which kind of examination best measured their level of understanding of the topics of photosynthesis/respiration and genetics. Duit and Confrey (1996) suggested that student interviews help provide deeper understanding of student insights. Feedback from the students helped to identify methods to modify teaching techniques coupled with the outcomes of the reasoning section of the diagnostic examinations. Interviews also established if student attitude and motivation supports or negates the average scores recorded from the standardized and two-tier diagnostic tests.

1.9 Significance

Constructivist-informed teaching is capable of enabling students to develop greater depth and more meaningful understanding of science topics while diagnostic instruments can assess this level of understanding more easily than standardized tests and students can reflect this in their interviews (Fraser & Tobin, 1991; Tsai & Chou, 2002). Standardized tests do not measure student understanding at a deep and meaningful level and therefore do not differentiate between memorized knowledge and a deeper understanding of that knowledge.

A problem that arises with current achievement examinations is that students who attain high scores on traditional standardized tests may not have a deep understanding of the topics on said examinations and this will be detrimental to their studies at higher academic levels. The contention from this study is that the use of multiple tier diagnostic items on any given topic in advanced Living Environment classrooms can better establish the level of understanding of course outlined topics.

This is significant because state-wide assessments may need to be reevaluated to determine if students have actually achieved average skill or mastery of the Living Environment curriculum topics as per the No Child Left Behind Act established by former President George W. Bush. Also, if the target student population establishes a lack of understanding, both teaching and testing styles should be modified to promote further understanding.

In summary, the significant outcomes of this research study include the following:

1. The provision of a framework for creating a learning environment suitable for the needs/goals of all students specifically using constructivist teaching practices. This study provides tools to initiate curriculum assessment based upon students' particular goals for their future directly correlated to teaching and learning in the Living Environment classroom. This study is relevant because it established a correlation between what was taught and learned in the advanced Living Environment high school science classroom. Overall, the comparison of learning assessments using diagnostic two-tier examinations and the level of understanding attainment measured by standardized past Living Environment Regents examinations was not correlated even within the same student population demonstrating the shortcomings of the prior examination.
2. The rationale behind tackling this research was to address the shortcomings of the NYS Living Environment Regents Examination to assess student learning and understanding. The No Child Left Behind Act and the New York State Education Department should re-assess if student learning and understanding is best measured using current achievement instruments.
3. Student perception of science, coupled with self-motivation, is directly proportional to academic success and student attitude in the learning environment. Educators can use this information to determine which actions need to be taken to resolve quandary in the learning environment. Olmesdahl (1999) states "Serious thought, and action, needs to be taken in respect to the mode or style of teaching and the curriculum itself." If change is required to foster the best performance of students', this should be pivotal in the mission

of creating a cohesive learning environment that includes suitable achievement measures.

1.10 Limitations

Several limitations arose over the two year period during which data were collected for this study. This study was limited to only 163 highly skilled Living Environment students who attended a middle class school in Long Island, New York. It was the only school used because of the inability to retrieve complete data (constructivist practices, sample/practices items for each achievement measure, standardized tests, Living Environment Regent's scores, and diagnostic test scores in totality) from other voluntary participants. Incorporation of results from a small population of students in Long Island, which may not support the entire population of high school science students' nationwide, is a limitation. The use of stratified sampling (males vs. females) and providing numerical correlates for the student data increases random chance and ambiguity caused by the researcher, identifying and testing a small population of students to diminish the overall limitation caused by the similarity within the population demographic. The researcher was the constructivist teacher deemed by characteristics which define constructivist teaching practices while instructing the advanced Living Environment courses.

It is significant to note, previous literature has not been identified comparing two-tier examination questions to the standardized New York State Living Environment Regents questions. The lack of previous validation for this work may lead to issues of reliability of outcomes but the qualitative outcomes per student sample to correlate the collected data may serve as a means to adjust for this discrepancy.

Another limitation includes the lack of validation of the new items added to the genetics two-tier diagnostic examination because the second tier questions were created specifically to test the ideas of this student population and deviates in this context from previously validated instruments (Haslam & Treagust, 1987; Tsui & Treagust, 2004). Also, students may have misinterpreted options in the two-tier multiple choice diagnostic instrument because the form of examination was the first of this kind for the participating students. To offer recourse for this discrepancy,

students who asked were given clarification of testing instructions repeatedly and at will. Students may have guessed at questions they were unsure of therefore affecting validity and reliability of all examinations administered. Because students were all given the same examinations (standardized, two-tier diagnostic, and NYS LE Regents) reliability may still be assumed.

As with any teaching or testing activities, lack of identifying other variables, which contribute to student attitudes and achievement in the high school learning environment, might influence achievement scoring outcomes and serves as a limitation. Examples might include the effects of ethnic backgrounds, socio-economic status, or choosing only a suburban vs. urban population sample to conduct this research.

A final limitation includes the timing of the post-TOSRA examination. The post TOSRA exam for Year 1 was conducted at the end of the 2006 Living Environment Regents examination. This examination was 3-hours in length and the students may have been tired or frustrated after taking this examination to then sit and effectively answer 70 items relating to their attitude towards science.

1.11 Research Overview

The cumulative goals of the study were to compare the overall GPA's (grade point averages) of students as earned from standardized test, the Living Environment Regents, and two-tier diagnostic assessments within classrooms pre- and post-constructivist teaching of genetics and photosynthesis/respiration concepts. Overall this work examined the New York State implementation of a final Living Environment Regents examination to quantify measures that determine whether or not students and educators are achieving the goals of the No Child Left Behind Act and this utilization may be flawed.

In addition, relevance and support of the use of diagnostic instruments to measure understanding more readily than standardized tests was echoed in students' interviews. Diagnostic instruments can assess students' knowledge in such a way that teachers are inhibited from teaching towards the test. This approach supports the

premise and goals for the creation of the No Child Left Behind Act (2001). Empirical studies such as the one reported here can be used to determine whether or not students in classes of constructivist-informed teachers can achieve higher scores on diagnostic assessment tools and encourage students to attain a deeper understanding of the concepts presented within the high school science classroom.

Chapter 2

LITERATURE REVIEW – CONSTRUCTIVISM AND ASSESSMENT TOOLS

2.1 Overview of Chapter (Theoretical Orientation)

This chapter provides the literature review describing theoretical and methodological approaches which shape assessment of students and how constructivist teaching practices and two-tier multiple choice diagnostic examinations may better clarify student learning as an achievement tool. The chapter is divided into nine broad sections which encompass constructivist teaching approaches (Section 2.2), analysis of teaching and learning of gifted/advanced students (Section 2.3), learning and measure of assessments for understanding (Section 2.4) and the difficulties of statewide examinations to assess learning (Section 2.5). Analyses of genetics and photosynthesis/respirations concepts (Sections 2.6 & 2.7, respectively) for advanced student learning were revealed in this study. Finally, Fraser's (1981) *Test of Student Related Attitudes* (TOSRA) was examined (Section 2.8) and a summary of the chapter provided (Section 2.9). To conclude, this chapter explored some shortcomings of the New York State Living Environment Regents as an assessment tool for the aforementioned topics while learning in a constructivist classroom and the limitations which may prohibit proper assessment of advanced or not used before students' knowledge.

2.2 Teaching Approaches: Constructivist Informed Teaching

Above all, teachers teach because they want to share the gift of learning; particularly in the high school, students are instructed in topics of specific interest to the teacher. In order to effectively complete this task a teacher must be informed about how students learn. As part of the role of a teacher, students must also be evaluated for what they have learned during a course of study. This literature review explores how constructivist-informed teachers used various tools to recognize student learning, reconstruct and deconstruct misconceptions, and clarify information presented in

genetics and photosynthesis/respiration that concluded with a series of diagnostic tools and achievement measures.

2.2.1 Definition of Constructivism

Science education has moved away from student memorization of facts to encouraging students to develop deeper understandings of concepts within the specific science discipline being taught (Tanner & Allen, 2005). To teach students such that a deeper understanding is obtained, learners' preconceived notions or misconceptions must be acknowledged and resolved. Constructivism is a theory of how learners comprehend learning, mostly associated with knowledge acquired through active information seeking. Constructivist teaching promotes education by assembling viewpoints which include those of the learner, inclusive of several factors in the learning process, such as prior student knowledge and inclusion of world influenced activities (Bachtold, 2013; Jonassen, 2006; Northfield et al., 1996; von Glasersfeld, 1995). Construction of a learning unit of study includes effort on both the part of the student and the teacher to complete undertakings which encourage learning (Bachtold, 2013; Gil-Perez et al., 2002; Jonassen, 2006; Schreiber & Valle 2013; Steffe & Gale, 1995). Shared interactions and collaboration in concept understanding are the basis of constructivism (Treagust et al., 1996).

2.2.2 Constructivist Science Classroom (the Living Environment course)

Science knowledge is a compilation of identified concepts and associated actions deemed successful to modern life in the world; in brief, knowledge is adaptable. Science education reform is rooted in changing classroom practices to promote students' deep conceptual understanding of science via high-order thinking, reasoning, and problem solving (Tanner & Allen, 2005). In a constructivist classroom, learners, their peers, and the teacher collaborate to connect true life scenarios to concepts for student constructed learning. Three themes, commonly echoed in constructivist instruction include an emphasis on deep understanding, making connections with real world scenarios, and elaborate and authentic communication (Nie & Lau, 2010). Both cognitive and social constructs play a role in the acquisition of science knowledge.

The Living Environment course is a modified biology course and consequentially poses similar difficulties in student learning or in the deconstruction of previous misunderstandings during teaching. In addition, biology and therefore the Living Environment course include concepts of chemistry and physics that must be applied in teaching and assessments; particularly noted with photosynthesis/respiration and genetics topics. Active learning of photosynthesis/respiration and genetics must incorporate hands on learning techniques that decipher and deconstruct physics and chemistry misconceptions as well as biology misconceptions. There are multiple studies that address student misconceptions about photosynthesis (Lumpe & Staver, 1995; Mintzes et al., 2001). Understanding and assessment of the Living Environment course includes ideas and premises from prior branches of science (physics and chemistry) coupled with prior biology units incorporated into successive teaching units. If previously knowledge was not solidly ascertained by the student it may lead to difficulties in the understanding of newly proposed course units (Michael, 2006).

Cognitive constructivism proponents state that learning can be inspired by physical, social, or mental observances (Gil-Perez et al., 2002). Cognitive constructivism also suggests that understanding is equitable. Lasting understanding is thereby constructed via external experiences in the mind of the learner based on combining theoretical and methodological approaches. Therefore, understanding science requires the ability to take information and apply it correctly, given a specific universal situation (Wiggins & McTighe, 1998). Inquiry about common observations such as a battery's loss of power or how specific organisms are able to live in extreme conditions enables students to construct knowledge (Marzano et al., 2001). Science inquiry requires the use of higher-order thinking skills and is a complex construct but students of cognitive constructivist teachers can learn via personal assembly of information, derived from life and classroom experiences (Tanner & Allen, 2005; von Glasersfeld, 1995). Constructivism is comparable to inquiry based learning where the old adage states "Tell me and I forget, show me and I remember, involve me and I understand" (see Healey, 2005). Inquiry-based learning and cognitive constructivism are pedagogically equivalent approaches to science instruction which engage students in the questioning of preconceptions and allow

existing knowledge to be challenged (Bachtold, 2013; Furtak, 2006; Healey, 2005; Jonassen, 2006).

Cognitive constructivism in Piaget's work (stated in von Glasersfeld, 1995) and social constructivism, most commonly associated with Vygotsky (seen in Schrieber & Valle, 2013) share common paradigms which best define knowledge as not only designed within the mind of the learner but is the result of activities in a social environment that allows for the sharing, constructing, and deconstructing of ideas and beliefs to provide the framework of understanding (Nie & Lau, 2010). A social constructivist teacher not only provides the language necessary for education but also negotiates significance between two or more participants engaged in learning (Schrieber & Valle, 2013). Knowledge construction is completed through cognitive processing by individual learners and through social processes such as conversation and language (Nie & Lau, 2010).

Social factors such as language, culture, and a participant's (student and teacher) perspective of the content being learned dictate how social interactions are used in the constructivist classroom (Nie & Lau, 2010; Treagust et al., 1996). Language use and perception in the learning environment may dictate meaning of taught content leading to misconceptions, misunderstanding, or pertinent knowledge transmission. Furthermore, language stimulates feeling of community and promotes interactions between members of a group to share ideas for learning endorsement and clarification. Culture, which includes the beliefs and values of the participants', creates varied perspectives that reassign meaning for what is being taught and learned. Perception is the vantage point of the participant to interpret world interactions as a model for knowledge construction. Knowledge is created when participants use language, culture, and perspective to interact socially while combining theories presented; therefore learning is not solely in the student participant's mind but is due to many factors working in collaboration (von Glasersfeld, 1995).

2.2.3 Teachers role in a constructivist Living Environment classroom

Treagust et al. (1996) referred to the pedagogical statement made by Ausubel (1968) that encompasses the aims of constructivist teaching: “The most important single factor influencing learning is what the learner already knows...”. The most important facet to remember when effectively teaching students in a constructivist classroom was enveloped in the prior sentence. Constructivist teachers sometimes play a more peripheral role in student learning by supplying thought-provoking activities while allowing the students involved in the activity to derive personal meaning and develop an understanding of the information presented.

Traditional teachers usually encourage students to memorize facts associated with course content and most answers to questions are provided directly to the student in practice for future achievement measures. In contrast, constructivist teachers are facilitators who provide resources that allow for multiple methods of inquiry-based activities, even if structured, to prod student learning and have designed a variety of assessments (including open ended questions/free response, unique laboratory activities, simulations, learning centers, and cooperative group activities to debate and discuss content in accordance with student lives while preparing for testing) which encourage higher order thinking and problem solving (Brown, 1999). Assessment of student learning is combined with teaching and occurs through multiple modes; the teacher makes observations of students in classrooms and at home with written assignments, student laboratory activities, group projects, examinations and portfolios (Kim, 2005).

Traditional teachers may favor direct instruction but research on the role of students’ pre-instructional conceptions in learning dictates disseminating knowledge with the student’s point of view in mind as a necessity for learning (Bachtold, 2013; Treagust & Haslam, 1987). Chen (2012) referred to the constructivist teacher as one who does more than just assign projects but is an integral part in how students learn; they are the facilitators of learning. Constructivist teachers provide teaching modalities which allow students to actively create protocols that allow for opportunities to learn and build knowledge.

In 1990, the National Research Council identified biology education problems in United States high schools and in 2003, concerns were also voiced about biology teaching and learning in undergraduate education. Teaching approaches that more actively involve students in the learning process, including student driven problem solving as well as memorization, will lead to more long- lasting, understanding (Michael, 2006). Engaging students in activities such as problem based or case-based learning including collaborative learning, group work, and cooperative activities that include peer instruction force students to reflect upon ideas and how they are using those ideas to enhance understanding in a particular discipline (Michael, 2006). Constructivist teaching styles which include the variety of techniques listed above will assist in enhanced understanding, greater achievement, and possibly evokes science related attitude changes in students (Crouch & Mazur, 2001, Huang et al., 2010; Olmesdahl, 1999). Multiple pedagogical techniques, such as concept mapping, could be used to establish concept learning and dispel misconceptions as biology lends itself to hierarchical organization of concepts (Novak, 1996; Michael, 2006). Briscoe and LaMaster (1991) stated concept mapping leads to meaningful learning and Michael (2006) referred to an Eisobu and Soyibo (2001) study that showed significant learning enhancement and understanding via concept mapping, because it provided opportunities to practice skills, review work and gain feedback. The acquired skills and measure of understanding was evidenced quantitatively in achievement score increases.

Team based activities including group laboratory activities, group concept map creation, cooperative exploration groups, etc. if properly implemented could enhance retention of knowledge, lead to more profound understanding, and more positive attitudes towards the topics taught (Michael, 2006). Student attitudes towards science may change when learning in a group because peer support enhances learning capabilities (Huang et al., 2010). Students are more likely to learn and present with increased achievement when learning takes place within a group (Holt & Willard-Holt, 2000; Michael, 2006).

A teacher in a constructivist classroom serves as the coordinator of knowledge. The teacher creates and guides experiences for student learning while capitalizing on differences of students' understanding of content conceptions. Teachers must

acknowledge that student learners come to the learning environment with pre-existing knowledge and before sufficient understanding takes place this knowledge must be examined. Prior student knowledge may need to be deleted, modified, or integrated with previous information before teaching new subject content (Brown, 1999). Another role of a constructivist teacher while probing student conceptions is to provide evidence for restructuring former perceptions which differ from current key ideas. Students may deeply hold onto conceptions that are not harmonious and are severely inaccurate when compared to current science views (Duit & Treagust, 2003) and true learning cannot take place without deconstruction of these ideas. In the constructivist classroom, the learners are given specific guidance about how to cognitively manipulate information as the inchoate for long-term memory (Steffe & Gale, 1995). The constructivist teaching approach may include the following steps: 1) engaging philosophies; 2) exploring current concepts; 3) proposing modifications to previous conceptions; 4) explaining the rationale for concepts and clarification; 5) taking actions to imbed knowledge (Kim, 2005). Finally, in order to adequately serve as education facilitators in a constructivist classroom, teachers must also re-evaluate their knowledge of course content, in this instance, the Living Environment (biology-based) curriculum to determine personal limitations and strengths. Social constructivist strategies may place high importance on student-driven learning, but this does not imply deficient teacher knowledge, skill, or control; the teachers' professional role and expectations to reform teaching strategies is the understructure of student learning (Northfield et al., 1996).

Several teacher challenges may arise and prohibit a constructivist methodology when instructing students in the science classroom. The teacher's role in a constructivist classroom is much more challenging because sufficiently allowing and promoting recognition, evaluation and re-construction of student thought processes is a difficult task (Gunstone & Northfield, 1994). Overall, to ensure student understanding after instruction surpassing that of memorization requires review or prior knowledge (Tanner & Allen, 2005), deconstruction of inadequate pre-instructional concepts (Duit & Treagust, 2003), teacher understanding of constructivism, and implementation of constructivist skills in the classroom. These constructs are time-consuming but can be advantageous for the student learner. Students who effectively undergo *conceptual change* and have a vast theoretical and holistic repertoire of

science can effectively answer higher-order thinking and novel questions in science (Gil-Perez et al., 2002; Steffe & Gale, 1995). Better informed students may become the leaders who create more sustainable energy processes, create new medical devices, improve technology and diagnoses and design treatments for disease. Restructuring existing conceptions using constructivist practices may allow students to take personal risks in their learning and increase student motivation to learn (Huang et al., 2010). As an aside, it might also bring levity to note; much of what is read in textbooks today about science may be considered a “misconception” over the next few decades therefore teaching styles and motivations must change with changing technological and societal influences.

2.2.4 Conceptual Change

“Knowing the facts and doing well on tests of knowledge do not mean that we understand” – (Wiggins and McTighe, 1998)

Student and teacher conceptions shape how students are taught and learning occurs (Duit & Treagust, 2003). Conceptual change takes place by deconstruction of habits and/or misconceptions on the part of the teacher/instructor and the student learner (Gunstone & Northfield, 1994; Tanner & Allen, 2005). Conceptual change occurs when the teacher provides new information to the student yet in light of prior knowledge and worldviews all differences are resolved to result in knowledge building. In biology (the Living Environment course), a conceptual change analogy might be to deconstruct the misconception of a young science student – “a jellyfish is a fish because of its name and it lives in the water”. With regards to aquatic life the student may have limited or vast knowledge but a list of conventions must be devised and taught to clarify classification of organisms which live in bodies of water. The teacher must provide counter examples which lay inside the realm of the student’s prior experiences or the student may not find any incentive to change previous notions (Duit & Treagust, 2003; McTighe & Wiggins, 2012). If students are provided with tools to identify why their beliefs are problematic only then will change, proper re-construction, and learning take place (Baird & White, 1996; Hewson, 1996; Tsui & Treagust, 2009; von Glasersfeld, 1995).

Conceptual change, even though vital to learning, presents significant challenges for the teacher and the student learner (Gunstone & Northfield, 1994). Middle school, high school, and college students enter the classroom with a significant knowledge base about biology/the living environment. Yet, the time necessary to investigate the depth of what students know and do not know, are confused about, and their preconceptions is sometimes prohibitive and limiting due to curriculum constraints. Identifying understandings includes multidimensional integration of information into a framework designed by the learner and encouraged by the teacher. Tanner and Allen (2005) summarized Wiggins and McTighe's (1998) definition of understanding the learning framework (*Understanding by Design*) as a collection of six features that encompass understanding in a complex, multidimensional framework. A learners' conceptual framework of understanding must include the ability to derive meaning by *interpreting* (why the information is relevant and how it relates to personal growth (Baird & White, 1996), *explaining* (how things work by experimentation, action or design), and *applying* (how will learning skills assist in building a larger foundation of knowledge and how can this skill or knowledge be used) while maintaining *perspective* (adequacy of content with regards to evidence presented), maintaining *self-knowledge* (what does the learner truly know or not know about a given topic), and *empathizing* (how do others perceive the information and how do opinions differ; Baird & White, 1996) with regards to what is being learned (review in Tanner & Allen, 2005). Conceptual change can only occur if students are engaged in meta-cognitive (learning and processing of factors which control learning) analysis (Baird & White, 1996; Hewson, 1996).

Teaching with conceptual change in mind can greatly influence instruction, differentiation, and the daily goals of the Living Environment course. The teacher will be more aware of and design tasks (employ discovery learning; Hewson, 1996) which constantly review student learner perceptions thereby enhancing daily activity for learning. Teachers can use student alternative conceptions in creating distracters/"wrong answers" during assessments and use these assessments to identify conceptual change. The teacher should establish goals to promote student thinking while providing assessments which sufficiently evaluate student learning processes. Learners, because of personal inclusion of their ideas in the learning process, should become more motivated to learn, trust in their ability, assess good

learning behaviors (Baird & White, 1996) while reflecting on learning, and use intellectual arguments to present their views (Hewson, 1996). When features of conceptual learning are successfully combined, conceptual change approaches are generally more successful than traditional teaching approaches to enhance learning (Duit & Treagust, 2003; Hewson, 1996; Tanner & Allen, 2005).

2.2.5 *Understanding by Design (UbD)*

Understanding by Design (UbD) was intended to enhance teacher planning and course structure while modifying curriculum formatting, assessment, and teacher instruction. McTighe and Wiggins (2012) established UbD as a means to communicate the basic aspirations of the constructivist classroom with seven main tenets. The framework of UbD for teaching and assessing student understanding with the transfer of learning includes (1) flexible curriculum planning, (2) focused curriculum development that encourages deepening of student understanding; to proficiently use learned knowledge and skills, (3) endorse student clarity of topic matter and promote transfer of learning with performance skills such as – “the capacity to explain, interpret, apply, shift perspective, empathize, and self- assess” (pg. 1) as indicators of knowledge, (4) teacher unit preparation should emphasize backwards planning of curriculum; think about assessment before planning a unit to teach [Backward Planning occurs in 3 stages - *Stage 1*: determine the complete content desired for students to know based upon national, state, and district goals (*termed*-enduring understandings), *Stage 2*: assess student learning (*termed*- essential questions), and *Stage 3*: create learning activities to identify goals established in *Stage 1*, (5) teachers serve as coaches of knowledge; constantly assessing for meaning and transfer of knowledge when reviewing student learner assignments and activities, (6) use the course curriculum guides (i.e. NYS Living Environment Standards, Key Ideas, and Performance Indicators) to correlate coursework against professional standards (NYSED, 2013), and (7) continued self-assessment of teacher performance and student achievement to adjust classroom curriculum to maximize student learning (McTighe & Wiggins, 2012). UbD was intended to help teachers create lessons which provide students with multiple opportunities to draw inferences and make generalization about science content while the teacher served as the support for learning. The learner must actively construct meaning from science

content, apply their learning, and obtain feedback on learned content as a means to improve (Wiggins & McTighe, 1998).

2.3 Gifted/Advanced Students

Declining job retention and school closures in New York State are increasingly tied to state assessment standards and student achievement scores. As a result of increasing public pressure regarding education reform, school/district/legislative accountability mandates delegated by the NYS Board of Regents are consequentially also increasing. School districts and teachers are encouraged to ensure the maximum number of students who can attain a level of a minimal competency in mathematics and science. Consequentially the majority of school resources are allocated for struggling students (Stanley & Baines, 2002). Gifted/advanced students receive less fiscal attention statewide than any other learning group and little curriculum time is spent to promote varied teaching methodologies for this population. School districts aim to ensure that the majority of students can pass the statewide commencement examinations, which are designed as lower-thinking assessments, thereby essentially neglecting the potential of individual (specifically gifted/advanced) students. Within the US, more states and districts mandate lockstep teaching and use statewide assessments to dictate curricular academic standards and compare outcomes to a student's ability; with minimal competency testing, high achieving students in US schools will continue to be under-represented in core curriculum teaching guides.

As previously stated, most statewide commencement examinations assess and measure minimal competencies. Unfortunately, most advanced students can pass statewide assessments during the first month of study in the respective area of study (Stanley & Baines, 2002). Minimal competency examinations do not account for the advanced ninth grade students who enjoy and comprehend college level texts yet are forced to participate in and review basic curriculum. Nevertheless the standardized test scores bolster the school district and state Regents' examination passing rate. Teachers rarely have the time or means to adapt instruction to meet the learning ability of gifted students (Brown, 2011). Egalitarianism is lost on the gifted/advanced populations in education even though enormous strides have been

made in research to understand the needs of academically gifted students (Stanley & Baines, 2002).

Special education, vocational education, and bilingual education funding is 173, 35, and 15 times greater, respectively, than for gifted students (Stanley & Baines, 2002). In New York State, funding for gifted education is 1% of the total amount spent for special or compensatory education (Stanley & Baines, 2002). Egalitarianism has promoted the sentiment that all students should receive the same educational experience but to what expense? All students should be provided with the opportunity to actualize their learning potential. Curriculum for all and therefore assessment for all is not sagacious; advanced students should also be assessed at an expert level (Adams & Wieman, 2010). In most other areas of society, with the exception of public education, separation to favor superiority (sports, medicine, architecture, art, music, etc.) is accepted, but for education, separation which should favor superiority is instead normalized towards the ability of the lower functioning majority as successful measures of competency and learning.

Student textbooks provide the evidence in the change in standards to conform to competency rather than increasing academic rigor. Textbook publishers have altered texts to include more images, graphics, and sidebars which promote understanding by the slowest learners (Stanley & Baines, 2002). Teachers have also modified their teaching style in “non-tracked” classrooms to reach the lower middle of the student body. Below average and average students dictate the pace for the classroom while the gifted students become the tutors for the slower students in the classroom. The gifted student is provided with fewer challenges and the smartest in the classroom are often bored and underproductive. Students need to be properly assessed such that the educational system can appropriately adapt to promote each student’s intellectual gain (Adams & Wieman, 2010; Fasko, 2001).

Assessments and achievement measures are fundamental in the learning process. If properly assessed, students can reflect on their own intelligence and how they learn. Achievement examinations should be contextualized as intelligence-fair with increasing methods to assess understanding. Assessments should track student growth over time as a measure of differences in giftedness or intelligence (Adams &

Wieman, 2010; Fasko, 2001). Fundamental teaching errors have occurred when gifted/advanced students, average, and below average students are compared to the same standard of learning and assessment. Environments which foster all intelligences will enhance the talents of all students; differentiating courses of instruction and achievement allows students to express learning in creative and personal ways (Willard-Holt & Holt, 1997).

2.4 Assessment Instruments: Standardized, Concept Maps & Diagnostic

Inquiry-based science standards and assessments especially designed to meet changing science teaching practices and learning to promote scientifically literate citizens has been a part of both national and state wide reform of science education in the last two decades (Day & Matthews, 2008). The No Child Left Behind Act (NCLB) required all states to test students beginning in 2007-2008 for science proficiency. As initiated via federal law, students in New York are tested in science in grade 4, grade 8, and at commencement levels if earning a Regents Diploma (Day & Matthews, 2008; Gross, 2005). Continuous and various means of assessing student knowledge are needed in constructivist science classrooms to meet changing times. Teaching toward conceptual change should involve formative assessment where teachers and students use outcomes to alter teaching and learning (Boston, 2002) including diagnostic assessments (Tan et al., 2002), concept mappings (Novak & Gowin, 1984) and free response questions to truly measure learning. Formative assessment allows the teacher and student to make response-driven changes to learning and teaching styles (Boston, 2002).

2.4.1 Standardized testing and statewide mandated examinations

Standardized tests, originally evidenced in China (6th Century CE), include any reproducible and deliberate method of administering, scoring, and interpreting a test (usually following a strict rubric and scoring guide for consistency of grading) given to any student. Standardized tests are usually timed and all students are given the same amount of time to complete the examination unless extenuating circumstances prevail (Mertler, 2007). In this type of testing, test items are usually selected-response items where only one correct answer is present and students' goal is to

select/identify the correct answer option. The test items are usually true-false or multiple choice questions because they are versatile, objective, easy to use and less influenced to predispositions with regards to answer selection (Caleon & Subramaniam, 2010; Williams, 2006).

Traditional science assessments in the United States include standardized multiple choice questions which test students' ability to recall facts and basic comprehension of science content. Scoring of traditional standardized examinations is usually quick and accurate, without bias, but test items fail to evaluate the rationale of the learning framework and outcomes due to random effects (Caleon & Subramaniam, 2010; Tan et al., 2005; Williams, 2006). Constructed-response/free-response questions on statewide examinations have increased presence over the last decade and can also be standardized but allow for teacher grader interpretation and assemblage of outcomes. Since 2001, in the US, legislative bodies (after the implementation of NCLB and an increasing number of state commencement examinations to assess learning) have created scoring guides for constructed response or free-response questions to reduce interpretation of the standardized question answers. Free-response questions with scoring guides can assist in identifying the one correct answer associated with the correlating question as a means to reduce biases of the scorers. The purpose of a standardized examination is to compare one student against another, under like conditions, for measure of achievement or mastery of content.

Students are asked items that have deliberate answers within their context (identified by Mertler, 2007 as *selected-response items* that contain only one correct answer), under specific time constraints, and are rated with rubrics designed to consistently score student answers. In recent years, *constructed-response items* have been included on most New York State Science Regents examinations as a method of encouraging student views or responses that foster critical thinking of a given topic. Scorer decisions do play a role in the grading process but the items are designed to keep subjectivity to a minimum and pre-determined rating rubrics are established to ensure peak consistency (Mertler, 2007). The purpose of a standardized test is to determine how well students understand the topics as outlined by, for example, The New York State Board of Regents.

2.4.2 *New York State Science Assessments (Regents examinations)*

The University Convocation in 1876 was the site for the authorization of the first New York State (NYS) Regents examination. The resolution declared to “institute a series of examinations in academic studies and to issue certificates to students passing the same” which has continued to the present (NYSED, 2013b; pg. 1). The first examinations were held in June of 1878 in five subject areas – algebra, American history, elementary Latin, natural philosophy and physical geography. After review of results during the first year, the Regents were offered in November, February, and June of each year in 42 topics until 1911 when several additional topics were included, inclusive of Biology (Ormiston, 1987). In the 1940s the examinations (science included) were primarily multiple choices and in 1987 the examinations began to incorporate free-response/fill-in questions. The Biology Regents course evolved after review of course assessment measures and in 1999 was coined the Living Environment Regents instead of Biology and all students were mandated to take and pass the examination in 2003 in order to graduate from high school with a Regents Diploma (NYSL, 2013).

New York State Regents examinations have been advocated as a powerful incentive for statewide, district-wide, and school-wide academic improvements. Incentives for enforcing Regents examinations include 1) providing indicators of accomplishment for students, with an ability to promote skills outside of high school; 2) promoting achievement as defined by external standards and not the classroom teacher or school; 3) allowing for focus on specific courses and content because examinations are designed by discipline; 4) providing a platform for multiple levels of achievement determinations (failure, passing, average, or mastery); 5) providing comparisons between groups of students since every secondary student in NYS must sit for a Regents examination in various disciplines since the changing of Regents guidelines in 1996; and 6) enforcing what students should know and study in a variety of subjects dictated by instruction (reviewed in detail in Bishop et al., 2000). Regents’ examinations also promote inquiry in all science disciplines due to a 1200 minute laboratory component mandated to be included for each science Regents examination. The desired goals of statewide assessments are to encourage

administrators, teachers, students, and parents to place a higher priority on academic success, learning and standards.

State-mandated tests are usually the result of legislative mandates implemented for accountability purposes; such examinations carry dire consequences regarding school ranking, college acceptance, overall student grade point average and acceptance into advanced placement courses. State-mandated examinations, classroom instruction, and content standards are designed in parallel based upon the particular states goals and legislation (Mertler, 2007). The New York State (NYS) Living Environment Core Curricula (NYSED, 2005) present key ideas (broad, unifying, general statements students need to know) and performance indicators (statements consisting of what students can do as evidence that they understand a key idea) which are demarcated to major understandings that serve as tools to shape science instruction, student learning, and assessment. In addition, students must complete 1200 minutes of laboratory work in order to qualify to sit for the NYS Science commencement (Regents') assessments. The NYS standards are cogent yet wide-ranging because the Core Curriculum only provides "a portion of content" identified to be learned in the Living Environment classroom (Gross, 2005). The NYS Core Curricula provides the basis to propose and design New York Statewide Living Environment syllabi and assessments.

2.4.3 New York State Living Environment Regents

The New York State Education Department (NYSED) website www.emsc.nysed.gov/ciai/cores.htm contains a general overview and links of information regarding the Core Curricula guides for all New York State Living Environment courses. To culminate the school year, students take the NYS Living Environment Regents (Jan. 2001- present) which is written and reviewed by teachers. The examination is three hours long and is given three times a year (January, June, and August). The examination itself has four sections (A, B, C, and D). Section A is completely multiple choice, relying on the recall of factual information, while section B and C are inquiry based, fill-in questions with several multiple choice and short free-response questions that are meant to assess content, processing skills, and concepts outlined in the Core Curricula. Section D consists of multiple choice

questions and open-ended/free-response questions meant to assess content, processing skills and concepts associated with laboratory skills.

Day and Matthews (2008) conducted an analysis of all June 2004 - August 2006 Living Environment Regents examinations to determine the actual percentage of questions which could be concluded to measure inquiry, based upon behaviors necessary to model inquiry. The NYS Learning Standards (NYSED, 2007) describe inquiry as a three-phase process (precursor, exploration, and analysis). In the precursor phase of question review, Day and Matthews (2008) identified only 6.3% of the questions as higher order thinking/inquiry assessing questions while 27.8% were deemed inquiry-based in the exploration phase and 66.0% were deemed inquiry in the analysis phase of the study regardless of the section of the examination (A, B, C, or D) under evaluation. No one section contained primarily inquiry questions as proposed by NYS Board of Regents/ New York State Education Department (NYSED) Rating Guide divisions for sections A, B, C, or D (NYSED, 2007). Many questions therefore intended for analysis of context, practical thinking skills, and understanding only tested for content knowledge (Day & Matthews, 2008). A discrepancy exists regarding whether these examinations can serve as proper indicators of science content quality (Stanley & Baines, 2002). In addition, the Living Environment Regents does not allow for formative assessment because by definition individualized feedback is not provided to tested students, only the Regents' score is available to teachers and students following the examination (Boston, 2002). As a whole, NYS Living Environment Regents' scores are only used to shape future curriculum guidelines.

In summary, the New York State Living Environment Regents Examination is a state-mandated test that was developed to assess the performance of NYS school districts in abiding by and meeting the learning standards for all secondary Living Environment science students. Instead, the NYS Living Environment Regents Examination and most other state assessments measure minimal competencies, not teacher expertise or student understanding (Stanley & Baines, 2002).

2.4.4 *Concept maps*

Concept maps are graphical tools for organizing and representing understandings of content in a constructivist epistemology (Novak & Canas, 2008). Concept maps are diagrams of nodes, each containing concept labels linked by directional lines which are also labeled with connectors (Ruiz-Primo & Shavelson, 1996; Zeilik, 2012). The content is linked via concept labels (words) on a line to indicate relatedness between concepts (Ruiz-Primo & Shavelson, 1996). Ruiz-Primo and Shavelson (1996) described the combination of two nodes and a connector as a proposition. A proposition is the basic unit within a concept map which can be used to determine validity of the relation drawn between two linked concepts. Novak and Gowin (1984) stated that concept maps are hierarchical in design, beginning with generalized content (top of map) followed by consecutive branching off with more specific and detailed concepts toward the bottom of the map. Graphical divisions are valued by the number of branching lines and degree of abstract differences, while the cross-links suggest conceptual amalgamation/cohesion (Rye & Rubba, 2002).

Current views on learning suggest a major shortcoming in understanding and enhanced problem solving skill hinges on poorly organized conceptual framework of subject matter. An individual's ability to conceptualize concepts within a given discipline will dictate how readily new knowledge is acquired and thereby proceeds from low-order thinking to high-order thinking skills (Zimmaro et al., 1999). Concept maps can provide a foundation for learning because they can identify prior generalized concepts held by the learner to which developing conceptual frameworks can be attached. Further, the learners' prior knowledge can be connected with present detailed and specific knowledge to bridge gaps in understanding. When used as a diagnostic assessment tool, most importantly the learner must choose to make the learning exercise meaningful (Novak & Canas, 2008). Teachers should use concept maps as a student or group driven formative assessment evaluation (Boston, 2002).

By design, concept maps create meaningful relationships between ideas and can be used to facilitate learning and assessment because they serve as a template to help organize and structure knowledge (Novak & Canas, 2008; Novak & Gowin, 1984). Theoretically, concept maps are derived from assimilation theory where propositions

with two or more concepts linked by another term create connections of thought/concepts (Zimmaro et al, 1999). Concept maps have been used for over 40 years to provide visual and cognitively challenging charts to illustrate student knowledge of specified subject matter (Novak, 1996; Zeilik, 2012). As an assessment tool, concept maps can measure the degree of declarative knowledge presented by the student (Ruiz-Primo & Shavelson, 1996). If used correctly, concept maps can be powerful assessment tools for exploring and documenting the complex nature of biological domains (Mintzes et al., 2001).

2.4.5 Constructing concept maps

Concept mapping is both a taught and learned skill. Concept maps reportedly measure an individual's propositional comprehension, for example, in an area of science (Zimmaro, et al., 1999). Students must use adequate vocabulary to describe connections between nodes using concepts labels (lines) and express relevant idea's logically. Terms on the lines express meaning of the two concepts relationship interconnected by the line. During the construction of a concept map, teachers must encourage students to use learned terms, facts, and concepts associated with the subject matter as a means to construct an initial graphical representation of content knowledge. The teacher's initial instruction must include the organization of content into meaningful categories with integration of information, ideas, and concepts. Teachers may begin a concept map for students to replicate and revise using their own hypotheses about taught ideas. Beginning the construction process with a domain of knowledge that is familiar to students may encourage good map construction for the novice concept map maker (Novak & Canas, 2008). The teacher should offer creative perspectives and analogies regarding the taught information to perpetuate long term memory and associations of knowledge. The construction of concept maps may instill higher level thinking skills, strategies and habits into that of the student learner (Zeilik, 2012).

Concept map construction can be made within groups, fill-in or selected fill-in's based upon teacher time and goals. Teachers can guide concept map construction in the following ways (as described by Zeilik, 2012): direct student concept map creation via 1) *Selected Terms Concept Mapping* which includes providing a list of

10-20 concept labels that can only be used once during the construction of the concept map; 2) *Seeded Terms Concept Mapping (Micromapping)* which contains all the nodes with select concept labels (5-10) in addition to the student adding an additional 5-10 concept labels to construct a complete map; 3) *Guided Choice Concept Mapping* which includes a prescribed list of 10-20 concept labels where students select 10 to create the map; 4) *Guided Context/Parking Lot Concept Mapping* includes providing a list of 30-40 hierarchical terms as nodes about the key concept and allow students to choose any concept labels to direct understanding of the key concept to create their map (Novak & Canas, 2008). Overall, each technique allows for restructuring of students' knowledge frameworks and brings clarity to the big picture of complex units of study (Kinchin, 2011) as maps are assessed and returned then revised for accuracy of science concept presentation.

2.4.6 Assessment use and scoring concept maps

Concept maps are powerful evaluation tools when students map out terms as a set of related concepts in a given topic of instruction. Students must organize terms based upon a hierarchical framework with linking words that describe relationships. If completed accurately, concept maps can denote whether students properly synthesized information, have detailed knowledge of specific concepts and can quantify understanding of definitions (Novak, 1996). Teachers can use concept maps to gain insight on how students view science topics, as a means to analyze misconceptions and construction of science concept framework of students, and finally, to access the structural framework of concept relationships as perceived by the student (Zeilik, 2012).

Concept maps as assessments provide meaningful review and reflection of student knowledge. Scoring of concept maps can take up to 10 minutes per student but they provide teachers with information about shortcomings in instruction of concepts and learner propositions. Initially, concept maps should be qualitatively analyzed. Educators should identify the presence or absence of concepts, position and terminology of links as scientifically accurate, the degree to which hierarchy and cross-linking are displayed, and does the student embrace large misconceptions based upon propositions suggested. Quantitative review of concept maps should be

based upon a scoring rubric to provide consistent and reliable concept map scoring (Lin & Hu, 2003; Novak & Gowin, 1984; Rye & Rubba, 2002). Overall, analysis of and use of concept maps as tests can be time-consuming and present difficulty when comparing students against one another for systematic and standardized evaluation. In addition, scoring of concept maps is crucial yet subjective, specifically for the novice teacher, while extremely worthwhile for student learning.

Concept map rubric scoring can be categorized based upon structure, content, integration and elaboration of the map (Lin & Hu, 2003). *Structure* relates to the degree that the outline appropriately follows concept map formatting; *content* scoring denotes agreement of concepts as expressed through teacher instruction; *integration* deals with the incorporation of content knowledge outside of teacher instruction and reordering of ideas to build a novel while accurate framework model, and finally *elaboration* scores the incorporation of ideas (via new words or analogies to describe connections) outside the realm of instruction (Zimmaro et al., 1999). Teachers must examine all nodes and linking words within the map to establish validity and accuracy of connections if using the concept map as tools of review and learning. If concept maps are properly reviewed and critiqued, students can learn much about their misconceptions and deficiency of the content learned before and after instruction (Novak, 1996). Concept maps provide a stepwise transparency of knowledge transfer as a valid assessment task.

2.4.7 Two-tiered multiple choice diagnostic tests

Teachers generally learn about student misconceptions from questioning or interviewing (Chandrasegaran et al., 2007; Treagust, 1988). Diagnostic tests are tests whose main purpose is to determine how much students have learned in a specific content area; this assessment provides insight to academic challenges or strengths (Mertler, 2007; Sesli & Kara, 2012). A diagnostic test's goal is to conclusively determine the achievement acquired by an individual or group of students without interviews. Tamir (1991) proposed and determined multiple choice test items with student justification of answer choices provided information about student's alternative conceptions and this type of testing was effective in assessing learning without the limitations of traditional multiple choice tests. From this premise, two-

tier, multiple choice diagnostic tests with specific guidelines were created (Treagust, 1998). Diagnostic examinations challenge student understanding of given topics by expecting support of deliberate *selected-response items* (tier-two) as a means to meaning? (Chandrasegaran et al., 2007). The overall goal of two-tier diagnostic assessments is to inform the classroom teacher of students' prior knowledge with alternative conceptions and to probe for deeper understanding of concepts based upon student perceptions and relatedness to taught content (Tsui & Treagust, 2010).

Diagnostic examinations apply nomothetic methodologies to evaluate student misconceptions and misunderstandings (Tsui & Treagust, 2010) against general scientific laws. Two-tiered multiple choice diagnostic tests include a first tier item (traditional, content factual, standardized multiple choice question) followed by a second tier item which ascertains the learners ability to justify the first tier answer; usually provided as either a multiple choice answer or free-response answer (Caleon & Subramaniam, 2010; Chandrasegaran et al., 2007; Griffard & Wandersee, 2001; Sesli & Kara, 2012). The goal of the second tier answer is to determine if the test taker understands why the first tier answer chosen is the most accurate answer from a scientific standpoint or to ascertain student misconceptions (Chandrasegaran et al., 2007; Haslam & Treagust, 1987; Treagust, 1988). In addition, the second tier question and justification provides a perceptive and efficient way to assess learning while performing as a diagnostic tool (Tamir, 1991). It is important to note that the teacher must have superior understanding of the topic subject matter in order to adequately assess second tier diagnostic examination free-response statements.

Treagust (1988, 1995) has provided guidelines for the development of two-tier diagnostic tests specifically to assist in identifying students' alternative misconceptions about science concepts (Chandrasegaran et al., 2007). A well designed two-tier diagnostic test would contain the correct reason to a standardized, traditional multiple choice question, followed by a secondary question containing three alternative choices (distractors) previously identified in research as misconceptions of students and one accurate reasoning choice with a fill-in option (Chandrasegaran et al., 2007; Duit et al., 1996; Treagust, 1995; Haslam & Treagust, 1987; Tan et al., 2005; Peterson et al., 1989). Several diagnostic tests have been developed for diagnostic assessments in many branches of science (Chen et al., 2003;

Chandrasegaran et al., 2007; Haslam & Treagust, 1987; Kilic & Saglam, 2009; Sesli & Kara, 2012; Tan et al., 2002; Tan et al., 2005; Tsui & Treagust, 2009) and hopefully the use of two-tier diagnostic instruments will not only assess student learning but also improve teaching and learning of specific science topics.

As a means to present dual sides of multiple choice two-tier diagnostic examination use, Griffard and Wandersee (2001) argued that a degree of error may exist in the second tier response descriptors due to poor clarity of student writing or explanation even when content is clearly understood and multiple choice written description of prior students' conceptual framework with forced choice second tier responses may read as slightly ambiguous. No examination type is infallible, yet finding the most efficient instrument to measure student understanding is necessary.

2.5 “Limitations” of Statewide Assessments

High-stakes association of student statewide examinations using standardized achievement tests began to increase in the 1990's and has been since used to measure teacher success and skill (Klein & van Ackeren, 2011; Sutton, 2004) along with student achievement. Student achievements and how schools use examination requirements from research findings have not displayed hoped-for positive effects, but instead has had severe side-effects. The reallocation of resources due to testing modifications, teacher tutoring, after school extra help programs, modified curriculums which teach to the test, fixation on short-term improvements, forbidden student assistance during examinations, and removal of innovative teaching methods are signature consequences associated with increased state-wide assessment (Klein & van Ackeren, 2011).

A major limitation of statewide assessments found in the literature, namely, the errors in statewide assessment scoring, have had serious implications for students, teachers, administrators, districts, and states. Students may be sent to summer school or a school may be marked as a needing improvement (creating poor press and increasing budgetary constraints due to corrective action) when scores are inadequately calculated (Herte, 2007). Due to the increased irregularities in statewide

assessments, since their inception, the U.S. General Accounting Office in 2002, recommended to the Secretary of Education (in 2002, Rod Paige) that a guarantee must be made to ensure accuracy and completeness of assessment data because it is central for measuring student progress. Yet without assessment scoring oversight, low performing schools may not be identified and a lack of confidence in assessments will exist (Herte, 2007). Problems prevail, for example, in New York State (June, 2003). A Mathematics A test required by law for graduation from high school, showed only 37 percent of students taking the examination having passed. Due to the immediacy of the issue to block student graduations, all seniors were exempt from the requirement but recommendations included revising mathematics standards, revising and creating a new scope and sequence for K-12 curriculum (making it clearer and easier to teach), and a new Math A examination was created. In addition, several closed investigations of alleged cheating (N=432) by school officials (teachers, administrators, aides, etc.) in New York State have been documented by the Education Department for scoring, grading and “improper coaching” during state examinations from 2002-2012 (School cheating, n.d.).

As a means to subside public pressure and scrutiny associated with statewide standardized commencement examinations, science Regents examinations have increased in difficulty over previous RCTs (Regents Competency Tests; NYS science exit examination prior to 1987) required by NYS for graduation. Increasing difficulty was correlated to increasing quality of New York State’s science education and academic standards. Another result which accompanied increasing technical and content difficulty and mandated requirements for graduation for all, were the necessity of more resources (time and financial) to assist struggling students (Bishop et al., 2000). As a result, struggling students’ achievement scores have increased but how advanced/gifted students are affected still needs to be reviewed. Overall, assessments should assist in improving each student’s achievement, improve instruction, measure mastery of content and skills of students and alter instruction as needed. The question prevails, are statewide assessments living up to their responsibility to assess all student learning? Gifted students typically present higher level thinking, problem-solving, and research skills yet are currently unassessed; assessments are limited in the ability to appropriately examine these areas (Brown, 2011).

A growing limitation noted in research indicates that the standards imposed through statewide testing in Kindergarten through grade 12 narrows curriculum to “teaching to the test” and encourages only basic skill content review (Sutton, 2004). Research reports encourage teachers to make their classroom assessments more aligned to statewide assessment formats as a means to make students more comfortable with commencement or statewide assessments (Herte, 2007) has diminished the relevance of assessing students overall.

An under-reviewed limitation of statewide assessments is the inability to adequately assess the multiple levels of intelligences identified by tested students. Not all students function at the same level, therefore statewide assessment do not take into consideration the learning ability of the wide variety of students in classrooms in NYS; advanced students, students with poor attitudes, students with inappropriate behavior, remedial students, unmotivated students, and average students are assessed with the same examination and held to comparable standards (Herte, 2007). The scores obtained affect both the student and teacher with long and short term impacts on education. Since the inception of NCLB increased testing infractions, testing irregularities, technology related “cheating”, teaching to ignore big ideas in favor of isolated, easily testable facts, and manipulation of testing data by administrators and teachers have been reported (Au, 2010; Herte, 2007; Reich, 2013).

With the exception of Day and Matthews (2008), no studies exist which review the decreased ability of the NYS Living Environment Regent’s to assess learning in gifted students even though the NYS Regents examinations are used for achievement purposes and dictate changes in curriculum design.

2.5.1 Interpretation of statewide test scores

Research confirms that statewide tests and examinations affect prior instruction and working structures (Klein & van Ackeren, 2011). The nature of high stakes testing on curriculum changes is highly dependent of the specific test structure (Au, 2007). All students will not achieve to the required standards because by design high stakes assessments are structured such that a limited percentage of students fail and/or

achieve mastery due to language or structure in order for the examination to be considered valid (Au, 2010).

Teachers understand that statewide test scores are important to district administrators, students and parents. Due to the enormous consequences and benefits of scoring, teachers while grading, may add personal judgments and ethical reasoning in grading practices (Seeley, 1994). Teachers grade the NYS Regents examinations during group, one stage marking periods with no anonymity of the student test takers; particular biases regarding their school and students may be present, coupled with tremendous time constraints associated with Regents grading (rushed scoring) and providing annual student scores (grading to ensure commencement ability). In addition, personal relationships, student attitudes, self-esteem, motivation, family background, etc. may influence how a question or series of questions are scored even in the presence of a scoring guide (Au, 2010).

Another under-reviewed concept with regards to statewide examination scoring and evaluation interpretation is that teachers might be inclined to believe low test scores have no correlation to unfair marking or teachings because the assessment is of the student and not themselves (Klein & van Ackeren, 2011). The Regents examinations and report cards outlining district level and school success can be used to both shame and inspire teachers to raise education standards (Bishop et al., 2000).

Distinctions between learning and assessment are blurred (Seeley, 1994) when interpreting scores on statewide assessments. The correlation between high-stakes testing and increased learning is questionable, empirically unproven and possibly false. Changes in test scores year-to-year and subject-to-subject have been observed with a 50 – 80% deviation in individual students and probably occur due to any number of random events (Au, 2010). High stakes examinations should measure learning but instead may sort populations along social, cultural, and economic lines. Consistently, gaps exist in passing rates of students in urban vs. suburban districts (NYSED, 2005) even with enhanced curriculum, teacher training, and tutoring.

Overall, policy makers have sought to reform US schools by establishing policy which includes testing students to ascertain which subject standards students have learned. Examination questions, asked in any assessment format (formative, multiple choice, free response, diagnostic, etc.) of the same skill level should identify overlap of content comprehension but remains undiagnosed with statewide assessments. If underlying cognitive skill exists in questioning, the overall achievement level should be comparable in similar students (Simkin & Kuechler, 2005). A single student should perform well (or poorly) on any assessment of similar content. Psychometric research and studies such as Tamir (1990) denote specific items on science assessments (statewide or summative commencement examinations) only accurately measured student knowledge 65% of the time. In addition, most achievement tests fail to have a high-enough subject content analysis (most tests lack difficult test items at the upper end) and truly fail to separate understandings of gifted/advanced students (Brown, 2011). The variety of implications associated in multiple findings show methods for assessing reliability and validity of high-stakes standardized assessments may be strengthened by including post-test interview data or recorded “think/talk aloud” sections. Currently, no changes have been made to correct for testing deficiencies but hopefully the overwhelming evidence against assessment interpretation will necessitate a change in testing policy (Reich, 2013).

2.5.2 Teacher pressures/expectations for students to pass state examinations

In order to hold schools and districts accountable for academic success of students, the No Child Left Behind Act (NCLB, 2001) ordered strict sanctions for districts that continuously failed to meet state established benchmarks regarding the education of all. Schools are required to meet benchmarks and submit adequate yearly progress reports to their respective states governing educational bodies (Dee et al., 2011; Herte, 2007). The Living Environment Regents student scores are reported to New York State and school districts use this information, not to specifically “assess progress” but scores are used as partial teacher evaluation criteria during the state-required evaluation called Annual Professional Performance Review (APPR). APPR must meet the criteria outlined in Education Law §3012-c and Subpart 30-2 of the Commissioner’s Regulations and obtain proposal approval. APPR was enacted in 2010 as a result of the NYS Board of Regents development and approval of Section

100.2(o) of the Regulations of the Commissioner of Education which required school districts to create an evaluation system of teachers who provided instructional services (NYSED, 2013). NYS Teachers' APPR scores include 20% composite scores from student "growth" on state assessments. The Regents examination score is also included as part of the student's overall score for a course, which is also evaluated in NYS teachers' annual performance. The creation of APPR scoring which includes student Regents' scores as part of the composite score of the teacher may encourage teachers to teach towards the test. Poor APPR scores over two consecutive annual reviews result in ineffective ratings; ineffective teacher ratings may implore administrative or teacher suspensions or job loss (Dee et al., 2011; NYSUT, 2013). Periodically the media will publish statewide, district examination results to bolster or defame individual schools (Dee et al., 2011) with positive or negative outcomes.

2.5.3 Teacher scoring and rating of NYS Regent's Examinations

To guarantee papers are marked in a reliable manner, marking standards have been created by the NYS Board of Regents and are distributed to scoring personnel prior to the commencement of scoring. Regents' examinations are graded by committee in a centralized location. Teachers are allowed to discuss student free response answers and scores but must follow the established scoring guide and use the "best potential answer" against possible alternatives as present in the scoring guide in support of all scores given. Periodically, scoring standards are altered after proctoring of the examination (Klein & van Ackeren, 2011). Teachers who have taught the test discipline are present during the scoring of their students. Teachers are not allowed to grade the entire Regents' examination of students in their classes even though the test is graded in committee during the scoring process.

2.6 Student Learning of Genetics

Secondary school/high school students have limited and prohibitive understanding of genetic concepts (Kilic & Saglam, 2009). Genetics is difficult to learn and teach (Gericke & Wahlberg, 2013). Many of the students' diverse genetic misconceptions stem from family, culture, religion, observations, perception, former teachers, and

experiences. Newly taught genetic information may challenge previous notions lead to a variety of unintended learning outcomes (Sesli & Kara, 2012). Consequentially, to provide meaningful conceptual learning, prior knowledge of students must be ascertained, then teaching and learning new concepts can occur (Ausubel, 1968); concept quality over quantity may create a cohesive framework for understanding interrelated concepts (Gericke & Wahlberg, 2013; Mintzes et al., 2001) in genetics.

Several genetics-based conceptual topics include the basis of heredity, structure of DNA, genetic replication and transfer, the building blocks of life (protein synthesis), genetic mutations, and genetic manipulation. Difficult vocabulary coupled with prior misconceptions make this topic extremely difficult to learn. Gericke and Wahlberg (2013) summarized five domain specific difficulties associated with learning genetics include learning vocabulary and terminology (Tsui & Treagust, 2004), coupling molecular processes with learned vocabulary, and mathematics associated with genetic manipulation. Teaching the entirety of genetics within a pre-designed curriculum (sequencing of teaching and learning genetics in a biology/Living Environment classroom) is time, teaching, and learning prohibitive, and understanding of the macro-micro organizational levels within organisms is usually lost in the context of completing the entire course load as outlined by NYS Regents' board.

Genetics can be taught in small groups or clusters of information to determine smaller, yet distinct understandings. Towards the end of the Genetics unit, the skill clusters can be combined and inter-related to show connectivity in the topic using, for example, concept maps. Well-designed net maps (complex concept maps) may be indicative of deep level of understanding with integrated understanding of concepts (Gericke & Wahlberg, 2013) in genetics. Difficulties of students in tying molecular and traditional processes in genetics may stem from differing frameworks found in textbooks but this requires further review. Functional aspects of genetics connections have shown to possess a deeper level of difficulty than structural aspects of genetics connections as seen in literature (Gericke & Wahlberg, 2013).

2.7 Student Learning of Photosynthesis/Respiration

Photosynthesis and respiration are two biochemical processes necessary for life on Earth. Organic, energy-rich nutrients are produced and utilized in photosynthetic and heterotrophic organisms from energy transferring reactions during both processes, using molecules from the environment. As a result, these topics are mutually taught in every Living Environment classroom in NYS. Photosynthesis, therefore conversely respiration, is rated as one of the most difficult of topics for students to master due to contradicting and prior knowledge about plants and biological functions of living things (Marmaroti & Galanopoulou, 2006; Ozay & Oztas, 2003; Schwartz & Brown, 2013). Several conceptual principles in these complex topics include autotrophic nutrition, heterotrophic nutrition, ecologic resources, biochemical processes and reactions, energy and its composition and transfer, chemistry, physiologic differences between organism Kingdoms, breathing and gas exchange, and waste products. Many misconceptions and misunderstandings exist due to the complex nature of ideas presented during photosynthesis and respiration instruction and learning; many students believe a multitude of false ideologies such as plants obtain food from soil, plants do not carry out respiration, respiration only occurs at night in plants (Yenilmez & Tekkaya, 2006), respiration is synonymous with breathing, nutrition is a synonym for feeding, plant respiration as an inverse gas exchange with animals, and plants are unable to survive without other organisms (Canal, 1999; Haslam & Treagust, 1987; Lin & Hu, 2003; Marmaroti & Galanopoulou, 2006; Ozay & Oztas, 2003; Tamir, 1990; Treagust, 1998). Basic prerequisite concepts about energy exchange, chemical equations (reactants & products), energy transfer, catalysts, and chemical changes exacerbate misunderstandings and prevalence of alternate conceptions in student learners. Students may also have difficulties discerning the human body as a chemical system (Chandrasegaran et al., 2007; Marmaroti & Galanopoulou, 2006; Treagust, 1988) and therefore have difficulty connecting biological processes and chemical reactions.

Several concepts should be taught prior to building concrete foundational knowledge about photosynthesis and respiration (elaborated in Canal, 1999): 1) distinguish the separate evolution of plants and animals; 2) differentiate between organism and cells and their correlation with another; 3) nutrition is a continuous exchange between an

organisms cells and energy sources; 4) differentiate between organic and inorganic substances with regards to their ability to provide energy for life functions; 5) nutrition is a process of obtaining inorganic and organic substances in order for cells to carry out life functions (nutrition is not eating); 6) green plants obtain inorganic nutrients from soil and air to perform photosynthesis, while living things obtain organic compounds and inorganic compounds (air) from the environment to carry out cellular respiration; 7) chlorophyll is the site of photosynthesis (to create organic nutrients) in autotrophic organisms and mitochondria is the overwhelming site for cellular respiration in all living things; 8) all plant cells use inorganic and organic substances to make compounds needed for life processes such as growth, respiration, and reproduction (Schwartz & Brown, 2013); 9) plants and animals equally complete respiration in the presence of oxygen to complete life processes and release carbon dioxide as a waste product; 10) respiration is not the same as breathing, respiration involves energy production and breathing is the acquisition of one of the inorganic compounds needed to complete respiration. Concept mapping may be used to bring clarity of student's understanding and inter-relate concepts (Lin, & Hu, 2003) prior to in-depth instruction of photosynthesis and respiration units.

A constructivist teacher must de-construct previous inaccurate or misunderstood concepts in a student centered environment, and then integrate biology and chemistry while developing the framework for both photosynthesis in photosynthetic organisms and respiration processes in all living things (Marmaroti & Galanopoulou, 2006; Ozay & Oztas, 2003; Schwartz & Brown, 2013; Yenilme & Tekkaya, 2006). Students must learn not to compartmentalize concepts and their relationships but to learn the importance of inter-relationships among various species while learning about biological systems (Lin & Hu, 2003; Schwartz & Brown, 2013). Additional studies should be conducted to determine if constructivist teaching approaches create long term memory of accurate concepts in once difficult to teach and learn topics in the biology/Living Environment classroom.

2.8 Test of Science Related Attitudes (TOSRA)

Research studies which have included assessment of science students' attitudes over the last 44 years have influenced inquiry-based instruction, constructivist instruction,

higher education choices, administrative policy and assessments (Lott, 2013). Attitude can represent feelings or opinions about a given subject, result in a physical reaction, or modify an individual's disposition. Since the works of Perrodin (1966), Klopfer (1971) and Fraser (1978) research has continued to grow in the field of student attitude assessment in the classroom. Klopfer (1971) in an effort to reduce confusion about the term "attitude" created a classification framework to categorize six distinct conceptual objectives in science but Fraser (1978) noted several major issues with instruments that followed the classification of science objects established by Klopfer (1971) thereby developing the *Test of Science Related Attitudes* (TOSRA) to rectify these issues (see comparison in Table 2.8.1; Fraser, 1981).

Table 2.1: Comparison between Klopfer and Fraser scales used in the development of the TOSRA (Fraser, 1981)

Named TOSRA Scales (Fraser, 1981)	Klopfer (1971) Classification	
Social Implications of Science (S)	H1	Manifestation of favorable attitude towards science and scientists
Normality of Scientific Inquiry (N)		
Attitude to Scientific Inquiry (I)	H2	Acceptance of scientific inquiry as a way of thought
Adoption of Scientific Attitudes (A)	H3	Adoption of 'scientific attitudes'
Enjoyment of Science Lessons (E)	H4	Enjoyment of science learning experiences
Leisure Interest in Science (L)	H5	Development of interest in science and science-related activities
Career Interest in Science (C)	H6	Development of interest in pursuing a career in science

The TOSRA has been internationally validated in Australia, Indonesia, Singapore, and the United States (Khalili, 1987). The TOSRA has also been used in a multitude of studies to review students' opinions on science related attitudes (Fraser, 1978; Joyce & Farenga, 1999; Khalili, 1987) in science classrooms. The TOSRA is divided into seven subscales which examine social implications of science, normality of scientists, attitudes toward scientific inquiry, adoption of scientific attitudes, enjoyment of learning science, leisure activities associated with science, and interest in a science career. The seven TOSRA scales, originally each contained 14 items which were reduced to 10 items (Schibeci, 1982) arranged on a Likert (1932) scale containing values of Strongly Agree (SA), Agree (A), Undecided or Neutral (N), Disagree (D), and Strongly Disagree (SD), scored 1, 2, 3, 4, 5, respectively (Fraser,

1981). Total scores for each of the seven subscales ranged from 10 (highly negative) to 50 (highly positive). The TOSRA questions have both negative and positive wordings to challenge the participant to carefully assess views before responding to an item (Fraser, 1981; Schibeci, 1982). In addition, to support the use of TOSRA in this study, empirical validation for TOSRA's seven subscales has been exhausted in many antecedent studies (Joyce & Farenga, 1999; Khalili, 1987; Schibeci & McGaw, 1981).

For this current study, the TOSRA was used in its complete form, prior to constructivist teachings in Grade 9/10 Living Environment classes (6 in total) and after 10 months of teachings in the same classes over two years. TOSRA was used in this study to investigate students' attitudes towards science providing a wealth of knowledge in a truncated period of time. To aid in validation, the data from these studies can be compared to two previous studies (Brown, 1996; Lott, 2003) which completed the same format of using pre-test/post-test data analysis of student attitudes even though their work showed contradictory outcomes. Brown implemented the pre-test/post-test use of TOSRA in a semester long Environmental Science course and determined there was a change in student science attitudes after exposure to inquiry based course instruction but Lott showed no change in pre-test/post-test attitudes towards science after a course of instruction. Lott (2013) used a modified TOSRA which assessed the subscales Attitude towards Scientific Inquiry, Enjoyment of Science Lessons, Leisure Interest in Science, and Career Interest in Science (40 items, total; deemed reliable with Cronbach alpha analysis). Neither interest in science nor interest in science careers increased after a course of study (Lott, 2013).

2.9 Overview of Chapter

This chapter presented a literature review that compared assessments and their use to measure and evaluate student learning as identified in several studies over the last four decades (Brown, 2011; Caleon & Subramaniam, 2010; Chandrasegaran et al., 2007; Klein & van Ackeren, 2011; Mertler, 2007; Sesli & Kara, 2012; Treagust, 1988; Tsui & Treagust, 2009; Williams, 2006). In addition, teaching styles, student perceptions and attitudes, and the reasoning for statewide/commencement

examinations were reviewed and compared to the under-representation of advanced/gifted students with Regents achievement examinations that test lower skill-level populations serving as the rationale for this epistemological review of achievement measures.

This chapter has reviewed assessments used in traditional and constructivist classrooms in the United States, with particular focus on the New York State Living Environment curriculum for two specific topics, genetics and photosynthesis & respiration. The NYS Living Environment Regents is pre-disposed to limitations in assessing understanding in advanced/gifted students. In addition, constructivist teaching approaches, comparison of assessments (such as standardized testing, concept maps, and two-tier multiple choice diagnostic examinations) and limitations of each in assessing student learning were explored.

This study aimed to establish a correlation between what is taught and learned in the advanced Living Environment high school science classroom while comparing the level of understanding attainment measured by using two-tier multiple choice diagnostic examinations, standardized multiple choice examinations and past Living Environment Regents examinations for achievement purposes. It is necessary to identify means to traditionally test science students without bias and effectively assess all levels of understanding during and after inquiry based learning.

This study examined the use of diagnostic tests in photosynthesis/respiration and genetics coupled with constructivist teaching approaches which included concept maps and assessment of previous naïve conceptions via interviews and measurements of student attitudes towards science to compare the assessment quality of standardized examinations, specifically the New York State Living Environment Regents examination, against two-tier multiple choice diagnostic examinations as a measure of advanced/gifted student learning over a period of instruction. This study proposed diagnostic multiple choice questions may serve as the assessment to rectify shortcomings of statewide assessments (most testing items embody lower order thinking) while removing bias of free-response answer grading, time needed to grade free-response questions and ambiguity of student meaning with open-ended questions coupled with the use of diagnostic tests to serve as an adequate models to

reevaluate science inquiry and learning in the Living Environment classroom. This study questioned if diagnostic tests can best assess understanding and learning of two difficult topics of biology- genetics and photosynthesis/respiration. The methodology for this study is outlined in Chapter 3.

Chapter 3

RESEARCH METHODS

3.1 Introduction

This chapter's purpose is to present the methodologies used to determine the relationship between testing instruments and advanced high school science students' knowledge of the New York State Living Environment curriculum in the topics of genetics and photosynthesis/respiration. The chapter is divided into twelve broad sections that includes the research methods that conform with the context of the study (Section 3.2), the study design (Section 3.3). These constructivist teaching practices (Section 3.4) and the research questions (Section 3.5) then details are followed by the Year 1 and Year 2 selected samples (Section 3.6); the instruments used in data collection (Section 3.7); how the data collected were used to draw parallels to each phase of the study including pen and paper instruments, administration of TOSRA, and the interviews (Section 3.8); and data entry (Section 3.9). Issues related to data entry and collection (Section 3.10) and data analysis which included descriptive statistics, inferential analysis, and triangulation of collected quantitative and qualitative data (Section 3.11) are presented prior to concluding with a summary of this chapter (Section 3.12).

3.2 Study Context

The initial idea for creating a project that investigated the impact of a constructivist-informed approach to teaching a Grade 9/10 advanced Living Environment Regents course was to identify assessments which assisted in meeting the challenges of the No Child Left Behind Act (2001). This act supports the idea of increasing academic standards with implementation of challenging curricula in order to attain high levels of achievement for all students. The premise exists that the measure of increased academic standards and consequential alterations of science curricula is best correlated with an increase of students' New York State Living Environment Regents examination scores. However, this outcome has not been appropriately supported by

the literature. To tackle this task, quantitative and qualitative data were collected to address the research questions outlined in Section 3.5.

Yin (1998) and Sutton and Staw (1995) agree that research findings are strengthened when multiple sources are used to gather data. Sources to gather data could specifically include: (1) achievement tests can be used to measure cognitive aspects of student understanding, (2) surveys can provide quantifiable evidence regarding affective attitudes towards science, and (3) interviews provide descriptive and valuable information from student learners about the learning process (Sutton & Staw, 1995). Hence, this study was designed to examine if constructivist teaching of two difficult to learn topics in the NYS Living Environment curriculum when assessed using a variety of quantitative and qualitative techniques and testing items could identify students understanding using specific and reproducible instruments.

3.3 Study Design

In this chapter, the methodologies for comparing a pedagogy of constructivist teaching compared to traditional teaching, the use of assessments (multiple choice practice questions, brief essays, homework assignments, probing questions, etc.) and comparison of tests against assessments (standardized multiple choice questions, New York State Living Environment Regents examinations and two-tier multiple choice diagnostic photosynthesis/respiration and genetics examinations) for measurement of student learning was used and supported by student interviews. Overall, this section discussed methodologies used to establish the assessment and achievement framework and to investigate student conceptions based on qualitative and quantitative analysis.

Finally, the incorporation of constructivist teaching practices allowed students to seize and take responsibility for their education in the 9/10 advanced Living Environment course that included the use of resources provided by their teacher (described in Section 3.4). PowerPoint slides were used as the main source of note taking as a means to establish continuity of didactic notes and as a mechanism for including visual resources to recapitulate skills taught in the photosynthesis/respiration and genetics topics (described in Sections 3.8.2 and 3.8.3,

respectively). The teaching of the course enabled students to review their own notes and ability to convey what they learned using concept maps (described in Section 3.8.4).

3.4 *The Intervention: Constructivist Teaching in a NYS Living Environment Classroom*

In this study, the teacher used constructivist-informed teaching activities to guide the learning processes that would most follow the Living Environment Core Curriculum guidelines (NYSED, 2008). Several of these activities included hands-on, inquiry-based tasks, laboratory reports, free-response homework assignments, essays, group assignments and projects, computer searches, video clips sourced from educational resources on the World Wide Web, data analysis, and student perceptions and interpretations obtained during direct communications.

The teachers' goal was to design lessons that were in alignment with the Living Environment Core Curriculum (for genetics and photosynthesis/respiration). In addition group "debates" as a means to broaden the understanding of students' learning via extrapolation of misconceptions and deconstruction of inaccurate knowledge in the advanced Living Environment high school science classroom frequently occurred. Students seemed encouraged to question one another and conclude why a statement of science was accurate based upon classroom teachings and learning from the variety of methods discussed earlier in this paragraph. In addition, group concept map creation (see example in Chapter 4; Figures 4.7 & 4.8) allowed for student correction and learning directly from peers with teacher support. These descriptive interventions were used to identify student misunderstanding or misconceptions of science concepts and establish consistency of content for learning photosynthesis/respiration and genetics. Following multiple interventions students were assessed with standardized and AP test items, followed by additional review and assessment with diagnostic examinations and an end of year Living Environment Regents Examination.

The University of the State of New York in conjunction with the NYS Board of Regents created the Living Environment Core Curriculum which outlines both Key

Ideas (broad and unifying statements all students must know) and Performance Indicators (statements which describe what students should know as evidence of learning and understanding of the Key Ideas) for the teaching and learning the Living Environment curriculum (for this study specifically photosynthesis/ respiration and genetics; NYSED 2007). The Living Environment Core Curriculum Guide has been written to be in accord with the goals outlined in *National Science Education Standards and Benchmarks of Science Literacy: Project 2061*. The guide should assist teachers and supervisors as they prepare curriculum, instruction, and assessments for the Living Environment component of Standard 4 of the New York State *Learning Standards for Mathematics, Science, and Technology* (NYSED, 2008). These standards state:

“Students will understand and apply scientific concepts, principles, and theories pertaining to the physical setting and living environment and recognize the historical development of ideas in science.” (NYSED, 2005, pg. 3)

The Living Environment Core Curriculum Guide is not presented as a syllabus to NYS educators/administrators but all content contained within the guide could be assessed at the commencement level via the Living Environment Regents science examination (NYSED, 2008).

Research recommends that the constructivist teacher should identify previous knowledge and establish relationships between concepts taught and propositional knowledge (see for example, Duit & Treagust, 2003). Hence the constructivist-informed teacher should incorporate the use of various learning tools such as concept maps, interactive web sites, free response homework assignments and laboratory activities to encourage a deeper level of student understanding in order to explore, introduce, and apply concepts learned in science while encouraging more scientific inquiry (Driver & Scott, 1996; Duit & Confrey, 1996; Judson & Lawson, 2007). Hands-on laboratory activities gave students an opportunity to review photosynthesis/respiration and genetics in an inquiry-based learning environment. Free response homework allowed students and teachers to explore what they believed as accurate answers for achievement items that may appear on

examinations. These classroom situations allowed the teacher to challenge or correct any misconceptions held by students.

After careful consideration of constructivist teaching practices and recommendations from the literature, further support is needed from empirical studies that students in classes of constructivist teachers can achieve higher scores on diagnostic tools and have a deeper understanding of the concepts presented within the secondary science classroom (Gallagher, 1996; Haslam & Treagust, 1987). This correlation will be reviewed in Chapter 4.

3.4.1 Technology in the classroom (PowerPoint's)

Within the last decade, technology has exploded in the educational arena. Students complete most assignments on the computer and most research is conducted on the World Wide Web. In order to meet the challenges of changing technology and consequentially teaching practices, the teacher researcher used technology to address less tangible concepts and to present fact-based information to students. Technology allowed for explaining abstract concepts, disproving or clarifying student derived theories, served as a source of printed notes to be allocated if absent from a lesson, and to review the work in preparation for achievement examinations.

Two PowerPoint presentations were made for Photosynthesis/Respiration and Genetics instruction, respectively, as the technology component of the lessons. The PowerPoint's contained factual notes of concepts but also included imbedded video clips, images, sites to review topic content, leading questions (to follow the Cornell method of note taking), open-ended questions, and hints to draw relationships between concepts. For example, a movie clip may show the process of genetically modifying corn for human consumption to increase yield and prevent insect infestations. During the video, additional information regarding long term ramifications of genetic manipulation was also addressed. This movie clip was used to 'debate' if genetic modification should occur, to discuss regulations associated with genetic modification, and to describe the overall processes involved in genetic engineering. Post video, the classroom was opened to discuss how genetically modified foods can affect future crop yields, health, and populations of limited

resources who may benefit from this technology. In addition, to reflect on TOSRA scales (Social Implications of Science, Leisure Interests in Science, Adoption of Scientific Attitudes, Normality of Scientists, Enjoyment of Science Lessons and Career Interest in Science) the discussion included potential careers in genetic engineering from working in the laboratory to farming and selling genetically modified vegetables/corn. The ‘debate’ began in class and ended with a homework assignment (usually essay format) where students expressed their opinion about genetic engineering from initial processing steps to distribution of food that had been genetically modified. Students’ assignments were graded and assessed for accuracy of content and presence of student opinion. Students were encouraged to cite and include outside readings which may reflect their opinion of genetic engineering with focus on adoption of scientific attitudes and discussion of the normality of scientists.

Movie clips aid in student understanding by providing visual representations of abstract concepts. It is generally estimated that approximately 85% of the population are visual learners (Spezzini, 2010) therefore videos can assist in solidifying understanding while deconstructing misconceptions or misunderstandings. For example, one movie clip showed a tangible visual representation of the structural framework involving enzyme activity specific to DNA during transcription and later mRNA, tRNA, and rRNA activity during translation to create proteins.

3.5 Research Questions

Yarroch (1991) stated the ability of students to correctly answer a question item or solve test problems is not indicative of concept understanding. More information is needed about actual concepts involved and how the answer was processed to establish the knowledge of the student. A variety of methods has been devised to evaluate concept understanding, achievement and attitude of taught concepts by students. These methods include surveys, standardized test items (multiple choice and free-response), concept maps, and manipulation of classroom techniques, interviews, diagnostic testing, and essay questions. In the following sections, the purpose of this study is examined using all previously listed techniques (except essay questions) to create the research questions for this study. The researcher ascertains that a measure of student understanding and the divisive measure of curriculum

understanding is not accurately measured using the current New York State end of year commencement tests (Regents examinations). A true measure of student understanding must come from quantitative and qualitative analyses to determine the significance of students' responses as a reflection of their understanding of taught curricula, from this, curriculum adaptations should occur. Therefore the following research questions were created to address this study's purpose:

Descriptive and inferential statistics for all tests

Research Question#1: *How do student attitudes correlate with scoring on standardized multiple choice examinations, two-tier diagnostic examinations, concept maps, and the NYS Living Environment Regents in photosynthesis/respiration and genetics?*

- 1a. What are the Cronbach alpha reliability measures and the mean correlations with other scales for the *Test of Science Related Attitudes*?
- 1b. What is the correlation between student responses on pre- and post-tests of the *Test of Science Related Attitudes*?
- 1c. Are there any differences between pre-and post-tests for all students on the *Test of Science Related Attitudes* (TOSRA), Year 1 & Year 2?
- 1d. Are there any differences between pre- and post-tests responses for males and females on the *Test of Science Related Attitudes*, Year 1 & Year 2?
- 1e. What are the Cronbach alpha reliability measures and the mean correlations with past-standardized multiple choice examinations, the two-tier diagnostic examinations and the Living Environment Regents examination in photosynthesis/respiration and genetics, Year 1 & Year 2, respectively?
- 1f. How do student responses compare on past-standardized multiple choice examinations, the two-tier diagnostic examinations and the Living Environment Regents examination in photosynthesis/respiration and genetics, Year 1 & Year 2, respectively?

Correlations between variables

Research Question#2: *How does advanced student understanding of photosynthesis/respiration and genetics correlate with gender of students and scoring on standardized multiple choice examinations, two-tier diagnostic examinations, concept maps, and the NYS Living Environment Regents?*

- 2a. What is the correlation between gender and total assessment outcomes and understandings of photosynthesis and respiration and genetics on past-standardized multiple choice examinations, the two-tier diagnostic examinations, concept maps and the NYS Living Environment Regents (Year 1)?
- 2b. What is the correlation between gender total assessment outcomes understandings of photosynthesis and respiration and genetics on past-standardized multiple choice examinations, the two-tier diagnostic examinations, concept maps and the NYS Living Environment Regents (Year 2)?
- 2c. Does a correlation exists between first tier and second tier responses on the diagnostic examinations in photosynthesis/ respiration (Year 1 and Year 2)?
- 2d. Does a correlation exists between first tier and second tier responses on the diagnostic examinations in genetics (Year 1 and Year2)?

Qualitative and Quantitative Data Triangulation

Research Question#3: *How does assessment type, student understanding, and student attitudes correlate with achievement scores on standardized multiple choice examinations, two-tier diagnostic examinations, concept maps, and the NYS Living Environment Regents after a course of constructivist teachings?*

- 3a. How do concept maps assist in student learning in a constructivist classroom?
- 3b. How do students socially construct understandings in light of positivist, quantitative research in the constructivist classroom and post testing?
- 3c. Which learning instrument do students perceive best assists in their understanding of photosynthesis/respiration and genetics?
- 3d. Which measure do students perceive best measures their level of understanding of photosynthesis/ respiration and genetics?

- 3e. What is the correlation between students' attitudes towards science, post instruction and their understanding of photosynthesis/respiration and genetics via interviews and assessment responses concept maps interviews in an advanced secondary science living environment course?
- 3f. What is the correlation between student achievement on past-standardized multiple choice examinations, the two-tier diagnostic examinations, concept maps and the Living Environment Regents examination and their understanding of photosynthesis/respiration and genetics in an advanced secondary science living environment course?
- 3g. What is the correlation between student achievement on past-standardized multiple choice examinations, the two-tier diagnostic examinations, concept maps and the Living Environment Regents examination in photosynthesis/respiration and genetics, when compared to student responses on the *Test of Science Related Attitudes* pre- and post-tests and student interviews in an advanced secondary science living environment course?

Duit et al. (1996) cautioned data research interpretation, especially from open ended questions, where the investigators interpretations may not actually match those of the student learner. The researchers' interpretation may actually refine the true answers as provided by students due to their own misinterpretation of students' understandings or misunderstandings. The researchers may read too much into the written statements, imbed their own ideas into student responses, and create responses for students where an ambiguity lies. In addition, students may give answers they believe the investigator/teacher want them to give even if contradictory to what the student believes. Duit et al. (1996) also suggested that multiple "snapshots" or learning processes over a period of time can provide more information about student development than investigating student understandings using one technique, at one time point. Stroboscopic analysis allows for sequenced review of student progress; better mimicking the learning process. This study's methodology outlines multiple techniques to observe student learning and development over a 10 month period in two consecutive years of study.

3.6 Student Sample/High School Demographics

The student sample comprised 82 students (Year 1) from three advanced Living Environment high school science classes and 86 students (Year 2) from three advanced Living Environment high school science classes within New York. The total study population was reduced from 190 to 168 students because a student participant was removed from the analyzed data set if they missed more than one survey, assessment, or achievement examinations and was unable to make up the assessment, survey, or examinations. The New York State Public School Report Card: Accountability and Overview and the Comprehensive Information Reports (NYSED, 2007a; NYSED, 2007b) were used to identify the student population based upon racial/ethnic origin, social-economic classification, and Living Environment Regents scores within the school district for the 2005-2007 school calendar years. The total attendance and suspension rates for this Long Island high school were 95%/96% (Year 1/Year 2) and 7%/7% (Year 1/Year 2), respectively. In 2005-2006, 26 students were eligible and took the Regents Competency Test with 73% passing rate and in 2006-2007, 8 students were eligible and took the Regents Competency Test with a 63% passing rate (NYSED, 2007a). The total graduates for 2005-2006 were 295 and in 2006-2007 were 291. Those receiving a Regents Diploma in 2005-2006 were 273, with 154 of those students also earning a Regents Diploma with Advanced Distinction; in 2006-2007 those earning a Regents Diploma were 260, with 152 earning a Regents Diploma with Advanced Distinction.

Year 1

Student Demographics

In this study year, a total of 35 males and 47 females were referenced in the sample. The total student population for the school during Year 1 was 0 or 0.0% American Indian or Alaska Native, 79 or 4.3% Asian or Pacific Islander, 31 or 1.7% Black (not Hispanic), 162 or 8.8 % Hispanic, 1561 and 85.2 % White (not Hispanic). No multiracial data were available for this time period. All students were generally of similar socio-economic backgrounds and ability (167 or 9% eligible for free lunch, 65 or 4% eligible for reduced-price lunch, and showed 98% socio/economic stability with 150 or 8% having limited English proficiency). The NYS Regents Examinations

in the Living Environment for 2005-2006 school years in New York State included 216,029 (NYSED, 2008) students tested and at this high school in Long Island, NY 335 students were tested. The number of students scoring 55-100 was 312 (93% of those tested), scoring 65-100 were 287 (83% of those tested) and the number of students scoring 85-100 was 87 (26% of those tested).

Year 2

Student Demographics

In this study year, a total of 40 males and 46 females were referenced in the sample. The total student ethnic population for the school during Year 2 included: 0 or 0% American Indian or Alaska Native, 79 or 4.3% Asian or Pacific Islander, 36 or 2.0% Black (not Hispanic), 204 or 11 % Hispanic, 1526 or 82.7 % White (not Hispanic). Again, all students were generally of similar socio-economic backgrounds. The NYS Regents Examinations in the Living Environment for 2006-2007 school years in New York State included 226,500 (NYSED, 2008) students tested and at this high school in Long Island, NY 345 students were tested. The number of students scoring 55-100 was 328 (96% of those tested), scoring 65-100 were 307 (89% of those tested) and the number of students scoring 85-100 was 97 (28% of those tested). The total population of 2006-2007 graduates from this high school, post- secondary plans included 272 or 93% plan to attend an institution of higher education (2-year institutions (36%) or 4-year (57%) universities or colleges).

3.7 Data Collection Procedures

This current study of teaching for understanding by comparing results of standardized tests and two-tier multiple choice diagnostic tests as achievement tools via constructivist teaching styles initially began with the implementation of a pre-test TOSRA (described in Section 3.8.1). These initial testing may have bewildered students who believed their opinions were generally not significant to their teachers. The post-test TOSRA was used to support the ideals and necessity of constructivist teachings to encourage science appreciation and learning.

Achievement was measured using past-standardized multiple choice questions, two-tier multiple choice diagnostic examination questions, and the NYS Living Environment June 2006 and June 2007 Regents Examination questions in photosynthesis/respiration and genetics as described in Sections 3.8.4, 3.8.5, 3.8.6, 3.8.7, and 3.8.8, respectively. Qualitative assessment of student learning included verbal, taped interviews which asked pre-prescribed questions in a structured and/or semi-structured format (Section 3.8.9).

3.8 Instruments Used to Collect Data

In order to answer the research questions as outlined in Section 3.5, this study involved the collection of both quantitative and qualitative data. *The Test of Science Related Attitudes* (TOSRA) was used to establish a preliminary student perspective about science during the pre-TOSRA survey while the post-TOSRA reflected student attitudes after approximately 10 months of learning in a constructivist science classroom (Section 3.8.1). The Living Environment Core Curriculum for conceptual understanding and curriculum development was reviewed for photosynthesis/respiration and genetics (Section 3.8.2 and 3.8.3) and training and creation of concept maps to foster constructivist teachings was described for later use as an achievement tool (Section 3.8.4). In addition, several instruments were used to establish student understanding. The instruments included previously administered past-standardized examination items to complement the primary modes used to assess advanced student achievement and learning in the Living Environment for photosynthesis/respiration and genetics (Section 3.8.5), two-tier multiple choice diagnostic examinations in photosynthesis/respiration (Sections 3.8.6) and genetics (Section 3.8.7) were outlined to focus on student understanding and reasoning. The New York State Regents Examinations (June 2006 & June 2007) for respiration and photosynthesis and genetics questions only was used to correlate outcomes with data perceived for measuring how well student understood taught lessons (Sections 3.8.8 and 3.8.9). Student interviews were used for quantitative and qualitative assessment and feedback (Section 3.5.10).

3.8.1 Administration of TOSRA

To measure students' attitudes toward their science class, *Test of Science Related Attitude* (TOSRA) was used (Fraser, 1978; Fraser, 1981). TOSRA was designed as a means to assess middle and high school science students' attitudes towards science (Joyce & Farenga, 1999). TOSRA uses seven scales which contain ten items each. The seven subscales include Social Implications to Science (S) that for example, would measure societal changes resultant of scientific discovery and whether those discoveries have had a positive or negative effect on society; Normality of Scientists (N) may assess how society perceives scientists lifestyles, for example, would scientists use Facebook®, Twitter, or other social media and go to the movies - this subscale goals to assess how similar the testing person believes scientists are to the general population; Attitude for Scientific Inquiry (I) for example, may assess predilections toward proposing a hypothesis and following through with experimental tasks to achieve an answer; Adoption of Scientific Attitudes (A) might assess the willingness to accept empirical and experimental data in support of changing a preconceived notion about science; Enjoyment of Science Lessons (E) aims to assess the level of enjoyment when partaking in science instruction; Leisure Interest in Science (L) evaluates the likelihood of the test taker to complete a science related act outside the academic arena, for example, to go to a science museum, read a science based book, or complete a science experiment at home for fun; and finally Career Interest to Science (C) measures the participants' plans to continue studying and working in a field/division of science after the commencement of formal education.

Student opinionated TOSRA test item responses range on a five-point Likert Scale (Likert, 1932), with the responses spanning from Strongly Agree (SA), Agree (A), Not sure (N), Disagree (D) to Strongly Disagree (SD). The TOSRA contains both positively and negatively worded items. The positive items are scored 5-1 (SA-SD, respectively) and the negatively items are scaled 1-5 (SA-SD, respectively). The mean score comparisons of the pre and post TOSRA student responses reflect if constructivist teaching practices enhanced student interest in science over 10 months of science teaching. The scales and a sample item from each are shown in Table 3.1.

Table 3.1: Scale Description and Sample Item for each TOSRA scale used

Scale	Scale Description	Sample Item
Social Implications to Science (S)	<i>Positive Item</i>	Money spent on science is well worth spending.
Normality of Scientists (N)	<i>Negative Item</i>	Scientists usually like to go to their laboratories when they have a day off.
Attitude for Scientific Inquiry (I)	<i>Positive Item</i>	I would prefer to find out why something happens by doing an experiment than by being told.
Adoption of Scientific Attitudes (A)	<i>Positive Item</i>	I enjoy reading about things which disagree with my previous ideas.
Enjoyment of Science Lessons (E)	<i>Positive Item</i>	Science lessons are fun.
Leisure Interest in Science (L)	<i>Positive Item</i>	I would like to belong to a science club.
Career Interest to Science (C)	<i>Negative Item</i>	I would dislike being a scientist after I leave school.

The *Test of Science Related Attitudes* were completed in three advanced Living Environment classrooms for Year 1 (N=75) and in three advanced Living Environment classrooms for Year 2 (N=80). In all instances, students had the directions explained to them while the instructions of the survey were read aloud; students were asked to read along. The purpose of the survey was explained to the students as a means to help the teacher-researcher acquire a clearer understanding of what effects student learning; to assist in modifying teaching styles and techniques. If questions were asked about the survey, they would be answered without predilection.

TOSRA was used to enable a quantitative measure of students' attitudes towards science prior to engaging in their teachers' instruction and again after 10 months of teaching to compare any changes in their overall attitudes towards the class and science in general. Pre-test TOSRA was given before the initiation of learning science in this researcher's constructivist classrooms. TOSRA's seven scales to ascertain student attitudes towards science should exhibit differences in student

attitudes when comparing pre-test TOSRA and post-test TOSRA data in this study's sampled student group (Year 1 and Year 2). The seven scale interventions after the initial pre-test TOSRA completion included factors to alter student attitudes about scientists, scientific inquiry, enjoyment of science, likelihood for each student to participate in science outside of the classroom and explore options about obtaining a career in a science field. For each TOSRA scale intervention procedures were employed which included but were not limited to the following: (1) Social Implications to Science (S) scale intervention included implementation of current, real-world examples that showed scientific discovery benefits for human life (i.e. the teacher researcher provided video clips that displayed techniques used to create genetically modified bacteria that produce human insulin at reduced cost and video's which explained novel techniques of environmental technology advancements to reduce waste by using refuse for fuel while at the same time reducing costs for energy production with alternative energy sources in reading passages); (2) Normality of Scientists (N) intervention included bringing in speakers of local research facilities and showing the students scientists are of all cultural groups, races, and ages; (3) Attitude for Scientific Inquiry (I) intervention included weekly inquiry based and cooperative laboratory experiments for each topic under investigation; (4) Adoption of Scientific Attitudes (A) intervention included providing fiction and non-fiction reading assignments to exhibit how understanding science has changed over the last century through a variety of means (i.e. reading and summary of *The Immortal Life of Henrietta Lacks*, watched the movie *Lorenzo's Oil* and read excerpts of the *Donner Party*); (5) Enjoyment of Science Lessons (E) intervention included interviews after a course of study prior to a new activity and post the new activity to identify what students perceived as the best techniques for enhancing understanding during the scientific learning process; (6) Leisure Interest in Science (L) intervention included initiating the Pet Club and Research Club as resources for students to evaluate their personal likes and dislikes about science outside of the classroom setting; and (7) Career Interest to Science (C) intervention included discussion of possible career options such as medical doctors, genetic counselors, social workers, professors/teachers of science, laboratory technicians, laboratory researchers and/or working in regulated research institutions as principal investigators for students.

Pre- and post-test administrations of the TOSRA will measure students' learning science attitude, individual science-related attitudes, their interest in science teachings, and science enjoyment in the Living Environment classroom. Students were told their responses were confidential, anonymity would prevail and scores would not be reflected in grading (semester class averages or annually) or for any other purpose outside of research practice; therefore students were encouraged to be as honest as possible when answering the items.

Study of TOSRA (pre-test)

During Year 1, the students were given the pre-TOSRA surveys within two weeks after the start of their advanced Living Environment class. During Year 2, the students were given the pre-TOSRA surveys within two weeks after the start of their advanced Living Environment class.

Study of TOSRA (post-test)

During Year 1, the post-TOSRA was given two days before the last day of classes, in the students' classroom, approximately one week before the 2006 Living Environment Regents examination. During Year 2, the post-TOSRA was given at the end of the three-hour NYS Living Environment Regents, at the end of June in classrooms without air conditioning. The students are mandated to stay for the Regents examinations up to two hours post commencement then can leave after this period if all sections of the examinations (A,B, C, & D) are complete. The teacher-researcher asked the students to stay after this time period to complete the TOSRA survey, the students obliged. The students would not have easy accessibility to the researcher after this TOSRA administration; school was closed to the students at the completion of these examinations. All pre and post TOSRA scores are documented in Chapter 4.

3.8.2 Living environments photosynthesis/respiration curriculum

The instructional material in photosynthesis and respiration as outlined by NYS Regents of the University of the state of New York and the NYS Board of Regents

was sourced from the Living Environment Core Curriculum guide. The Living Environment Core Curriculum guide loosely details content which was assessed on the NYS Living Environment Regents with regards to photosynthesis/respiration. The information is outlined in Standard 4; Key Idea 5; including Performance Indicators with major understandings outlined in section 5.1 (NYSED, 2008; see Key Idea 5 [photosynthesis/respiration] in Appendix I). Excerpts of the teaching curriculum guide are outlined (Figure 3.1).

Standard 4; Key Idea 5

Organisms maintain a dynamic equilibrium that sustains life.

Life is dependent upon availability of an energy source and raw materials that are used in the basic enzyme-controlled biochemical processes of living organisms. Organisms are continually exposed to changes in their external and internal environments and must continually monitor and respond to these changes. The result of these responses is called homeostasis, a “dynamic equilibrium” or “steady state” which keeps the internal environment within certain limits. Failure of these control mechanisms can result in disease or even death.

PERFORMANCE INDICATOR 5.1

Explain the basic biochemical processes in living organisms and their importance in maintaining dynamic equilibrium.

Major Understandings

5.1a The energy for life comes primarily from the Sun. Photosynthesis provides a vital connection between the Sun and the energy needs of living systems.

5.1b Plant cells and some one-celled organisms contain chloroplasts, the site of photosynthesis. The process of photosynthesis uses solar energy to combine the inorganic molecules carbon dioxide and water into energy-rich organic compounds (e.g., glucose) and release oxygen to the environment.

5.1d In all organisms, the energy stored in organic molecules may be released during cellular respiration. This energy is temporarily stored in ATP molecules. In many organisms, the process of cellular respiration is concluded in mitochondria, in which ATP is produced more efficiently, oxygen is used, and carbon dioxide and water are released as wastes.

Figure 3.1: New York State Living Environment Photosynthesis/Respiration Standards (excerpt; see Appendix I)

Standard 4 -Key Idea 2:

Organisms inherit genetic information in a variety of ways that result in continuity of structure and function between parents and offspring.

Organisms from all kingdoms possess a set of instructions (genes) that determines their characteristics. These instructions are passed from parents to offspring during reproduction. Students are now able to begin to understand the molecular basis of heredity and how this set of instructions can be changed through recombination, mutation, and genetic engineering.

The inherited instructions that are passed from parent to offspring are coded in DNA molecules. Once the coded information is passed on, it is used by a cell to make proteins. The proteins carry out most functions of the cell. Our current understanding of DNA extends this to the manipulation of genes leading to the development of new combinations of traits and new varieties of organisms.

PERFORMANCE INDICATORS 2.1

Explain how the structure and replication of genetic material result in offspring that resemble their parents.

Major Understandings

- 2.1a Genes are inherited, but their expression can be modified by interactions with the environment.
- 2.1c Hereditary information is contained in genes, located in the chromosomes of each cell. A human cell contains many thousands of different genes in its nucleus.
- 2.1f The chemical and structural properties of DNA are the basis for how the genetic information is both encoded in genes and replicated by means of a template.
- 2.1g The genetic information stored in cell's DNA is used to direct the synthesis of the thousands of proteins that each cell requires.
- 2.1h Genes are segments of DNA molecules. Any alteration of the DNA sequence is a mutation.
- 2.1i Protein molecules are long, usually folded chains, made from 20 different kinds of amino acids in a specific sequence. This sequence influences the shape of the protein. The shape of the protein, in turn, determines its function.
- 2.1k Different parts of genetic instructions are used in different types of cells, and are influenced by the cell's environment and past history.

PERFORMANCE INDICATORS 2.2

Explain how the technology of genetic engineering allows humans to alter genetic makeup of organisms.

Major Understandings

- 2.2a For thousands of years new varieties of cultivated plants and domestic animals have resulted from selective breeding for particular traits.
- 2.2b In recent years new varieties of farm plants and animals have been engineered by manipulating their genetic instructions to produce new characteristics.
- 2.2d Inserting, deleting, or substituting DNA segments can alter genes. An altered gene may be passed on to every cell that develops from it.
- 2.2e Knowledge of genetics is making possible new fields of health care. Substances, such as hormones and enzymes, from genetically engineered organisms may reduce the cost and side effects of replacing missing body chemicals.

Figure 3.2: New York State Living Environment Genetics Standards (excerpt; see Appendix II)

3.8.3 Living Environments Genetics Curriculum

The instructional in genetics material as outlined by the NYS Regents of the University of the state of New York and the NYS Board of Regents was sourced from the Living Environment Core Curriculum guide for the genetics topic. The Living Environment Core Curriculum guide loosely details content which will be assessed on the NYS Living Environment Regents with regards to the genetics unit and is outlined in Standard 4; Key Ideas 2; including Performance Indicators with major understandings outlined in sections 2.1-2.2 (NYSED, 2008; see Key Idea 2 [genetics] in Appendix II). Excerpts of the curriculum teaching guide for genetics are outlined (Figure 3.2).

3.8.4 Concept maps assessments and achievements

Concept maps, as outlined in Chapter 2, exhibit meaningful relationships between ideas as propositions. A proposition supports the validity of the relationship between linked concepts. Novak and Gowin (1984) suggest that the hierarchical design of a concept map can explain both generalized and specific concepts outlined on the map. Graphical divisions are valued by the number of branching lines contained within it to represent degree of differences, while the cross-links suggest conceptual unity. Concept maps can give the teacher a clearer understanding of what students perceive as a correct order of events regarding the topics taught. Concept maps have been useful in helping students learn how to learn (Novak, 1996). Concept maps may also be useful in identifying misconceptions or conceptions from past experiences, evaluate what has been learned, and encourage higher thinking in students (Lin, 2004, Novak; 1996).

Concept maps require training to learn and then should only be designed after students can extract meaning from content taught about a specific topic. Concept maps must be evaluated, reworked (several times if necessary), corrected for errors and meaning, then and only then should a final version can be used as an achievement tool. A considerable amount of teacher and student time is used to produce well-constructed concept maps.

In this study, the use of concept maps and their construction was taught to all student learner participants. Preliminary *Guided Context/Parking Lot Concept Mapping* maps were created in class on large sheets of white paper in cooperative groups during each topic's (photosynthesis/ respiration and genetics) course of study. The initial maps were designed in a group activity and the student obtained a list of terms to be used in the concept map by the teacher researcher (see Appendix III). The maps were critiqued by peers and the teacher researcher for flawed knowledge, weak concept labels, meta-cognitive analysis, casual relationships, degree of branching and suggestions were made for both design and content of the concept maps. Students were assigned to create a revised concept map (per topic of study) for homework to serve as a review and achievement assessment. Each student received the same list of terms for map creation which contained 30 subordinate concepts (nodes) for photosynthesis/respiration maps and 30 subordinate concepts for genetics; used at random by the student constructors (minimum of 20 nodes). Students' concept maps were scored and assessed for achievement. Students' concept maps were scaled from 10-1 on a rubric that explored students' understanding of the topics photosynthesis/respiration and genetics by assigning weights to hierarchy, propositional concepts and presence/accuracy of relationships (Besterfield-Sacre et al., 2004; Rye & Rubba, 2002; see Appendix IV for study rubric). A score of 15 (Year 1) or a score of 10 (100%; Year 2) represented a complete understanding of the topic; while a score of 1 (10%) represented very limited understanding of the topic presented. Note well, the teacher researcher does admit to subjective and somewhat arbitrary grading as noted by Novak and Gowin (1984) even with the use of the concept map rubric. Several students who obtained a score of 10 or 15, respectively, had several different degrees of exploration of topic summaries. Concept maps are acceptable tools to review propositional statements of photosynthesis/respiration and genetics. Additional items (interviews and free response questions) were also used to assess student knowledge.

3.8.5 Past-standardized test questions

Standardized test questions are traditionally used to assess student achievement. The New York State Education Department (SED) has implemented a commencement level examination to assess student achievement of various standards in science, in

this case, the Living Environment Core Curriculum (NYSED, 2008). Items from the New York State Regents Living Environment examinations circa 1986-2005 and Rules Wizard© for released Advance Placement Biology (College Board) examination items, in photosynthesis/respiration (45 items, 35 items; see sample items in Table 3.2) and genetics (50 items; see sample items in Table 3.3) were used in Years 1 and 2 respectively of this study to serve as an initial achievement measure and entirely consisted of traditional multiple-choice questions. The questions were written to contain one accurate answer and three or four distracters. These examinations creation goals were to assess advanced students' ability to apply, analyze, and evaluate material based upon content learned and skills acquired following the pre-determined standards as established by the SED.

Table 3.2: Sample Items from Past Standardized Regents. Items in Photosynthesis/Respiration (Items 1, 11, and 38, respectively; Year 1)

Lactic acid may be formed as a result of the process of
(1) anaerobic respiration
(2) aerobic respiration
(3) photolysis
(4) photosynthesis
At optimum light intensity, which atmospheric gas most directly influences the rate of photosynthesis?
(1) nitrogen
(2) oxygen
(3) carbon dioxide
(4) hydrogen
Most animals make energy available for cell activity by transferring the potential energy of glucose to ATP. This process occurs during
(1) neither aerobic and anaerobic respiration
(2) both aerobic and anaerobic respiration
(3) anaerobic respiration, only
(4) aerobic respiration, only

Students in grades 9/10 in the advanced Living Environment courses were required to take the standardized examinations in photosynthesis/respiration and genetics. Tests were administered directly after concluding teacher instruction in the respective topic. Tests were designed and aligned with the school districts instructional pacing guides giving students 44 minutes to complete the examinations, with the teacher researcher serving as the proctor. Student questions were answered during testing as long as the questions were not related to subject content. The

students scored the items on a Scantron© sheet and a Scantron© machine was used to determine student outcomes. The standardized examinations served as initial achievement examinations to assess student knowledge after a course of instruction (a sample of one full length standardized examination were designed from using the Examgen Wizard® for the Living Environment and A. P. Biology Examinations).

Table 3.3: Sample Items from Past Standardized Regents. Items in Genetics (Items 1, 7, and 29, respectively; Year 1)

Which structures code information for the inheritance of traits?	
(1)	nuclear membranes
(2)	cell membranes
(3)	vacuoles
(4)	genes
Two mice that are heterozygous for black coat color are mated. Assuming coat color in mice is controlled by a single pair of genes, which genotypic ratio for coat color is expected in the offspring?	
(1)	1:2:1
(2)	9:7
(3)	3:1
(4)	1:3:1
A human male will normally transmit the genes on his X- chromosome to	
(1)	His sons, only
(2)	His daughters, only
(3)	All of his sons and daughters
(4)	Half of his sons and half of his daughters

3.8.6 Two-tier multiple choice diagnostic instruments (photosynthesis & respiration)

The diagnostic instruments were transcribed verbatim, and duplicated for each student to complete. The photosynthesis and respiration items were sourced from Haslam and Treagust (1987) and Tsui and Treagust (2004) with permission, as a reliable and valid means to assess students' learning of biology. The instrument items were designed as two multiple choice parts with the first-tier, mainly a statement of fact and written as a traditional multiple choice question, followed by the second tier comprising multiple choice reasons (also with a blank space for inclusion of the students individual reason) for an answer in the first tier.

In this study, the diagnostic examination for photosynthesis/respiration was proctored following the directions on the original examinations as created by Haslam

and Treagust (1987) and Tsui and Treagust (2004). The students were given an answer sheet for the exam; the first tier-multiple choice included a short line, and for the second tier multiple choice, a longer line was given for possible explanations, if the second tier multiple choice answer was not chosen. The students were given 44 minutes to complete the examinations. Two-tier diagnostic instruments in photosynthesis/respiration (14 items total; see sample items in Table 3.4) were used in both Year 1 and 2. The complete diagnostic examination answer sheets and examinations for photosynthesis/respiration (odd numbered questions) are found in Appendix V and VI, respectively.

Table 3.4: Sample Items from Two-Tier Multiple Choice Diagnostic Examinations in Photosynthesis/Respiration. Items 4 and 15; Year 1 & 2

4. Which gas do green plants take in, in large amounts in the presence of light energy?

- (2) carbon dioxide gas
- (3) oxygen gas

The reason for my answer is because:

- (a) Green plants make their food from this gas in the presence of light energy.
- (b) Animals need this gas to respire in the presence of light energy.
- (c) _____

15. Which metabolic process is responsible for the muscle fatigue and cramping an athlete may experience after running a race:

- (1) alcoholic fermentation
- (2) aerobic fermentation
- (3) dehydration synthesis
- (4) lactic acid fermentation

The reason for my answer is because:

- (a) Pyruvic acid that accumulates as a result of glycolysis is converted to a byproduct of fermentation in the muscle tissue. This causes a painful, burning sensation.
 - (b) Ethyl alcohol and carbon dioxide are made in the muscle tissue as a result of fermentation. This causes a painful, burning sensation.
 - (c) All living cells use energy. As the energy is used up we feel pain and cramping in the muscle tissue.
 - (d) _____
-

The items were considered correct if an accurate choice was made for each section of a two-tier item. The distractors for both instruments items were previously determined and based on alternative conceptions identified using multiple choice examinations and essay based responses, literature research, and student interviews (Haslam & Treagust, 1987; Tsui & Treagust, 2004).

3.8.7 Two-tier multiple choice diagnostic instruments (genetics)

Two-tier multiple choice diagnostic instruments in genetics (15 items total; see sample items in Table 3.8.7.01) were used in both Year 1 and 2; the genetics items were sourced from Tsui & Treagust (2009) with permission, with slight modifications made by the researcher teacher (including the addition of two testing items) to address word use in a United States classroom as shown in Table 3.5. This examination was used as a reliable and valid means to assess students' learning of genetics.

The diagnostic examination answer sheets and examinations for genetics is found in Appendix VII and VIII, respectively.

Table 3.5: Sample Items from Two-Tier Multiple Choice Diagnostic Examinations in Genetics. Items 4 and 15; Year 1 & 2

4. Which one of the following is the best description of a gene?

- (1) The smallest unit of structure in a chromosome.
- (2) A sequence of instructions that codes for a protein.
- (3) A segment in a DNA molecule.
- (4) Don't know.

The reason for my answer is because:

- (a) It is about the information of a gene for producing a characteristic.
- (b) It is about the structural relationship between a gene and a chromosome.
- (c) It is about the chemical nature of a gene.
- (d) It is about the gene being a protein.

15. In mice, the gene allele *b* for white skin is recessive to *B* for brown skin. A male mouse with genotype *Bb* was mated to a female mouse with the genotype *bb* and then gave birth to a litter of 12 mice. How many mice in the litter are expected to be white?

- (1) 3
- (2) 6
- (3) 12
- (4) Don't know

The reason for my answer is because:

- (a) Half of the sperms but all the eggs carry the *b* allele.
 - (b) All the sperms but half of the eggs carry the *b* allele.
 - (c) There is only one possible fertilization event.
 - (d) _____
-

In this study, the diagnostic examination for genetics was proctored following the directions on the original examinations as created by Tsui and Treagust (2009). The students were given an answer sheet for the first tier-multiple choice; a short line was provided and for the second tier multiple choice, a longer line was given for possible explanations, if the second tier multiple choice answer was not chosen. The students were given 44 minutes to complete the examinations.

3.8.8 New York State Living Environment Regents Examinations – June 2006

The New York State Regents Examinations in the Living Environment – June 2006 was written to assess learning and ability of students. Teachers and supervisors prepare students for the examinations by following *The Living Environment Core Curriculum* guide Standards, Key Ideas, and Performance Indicators as previously noted (NYSED, 2008). The Core Curriculum’s goal is to help educators’ present major understandings that have subsets to detail student understanding and application of skills to scientific concepts, principles, vocabulary, and theories in the Living Environment course. This information should build upon knowledge and understanding acquired in earlier grades (NYSED, 2008).

“It is essential that instruction focus on understanding important relationships, processes, mechanisms, and applications of concepts. Far less important is the memorization of specialized terminology and technical details.”...“It is hoped that the general nature of these statements (*The Living Environment Core Curriculum*) will encourage the teaching of science for this understanding, instead of memorization” (pg. 3, NYSED, 2008).

The NYS Regents examinations are to assess student understanding as outlined by the SED and in *The Living Environment Core Curriculum*. The 2006 Living Environment Regents Examination consisted of 4 parts (A-D), but only one section (A) consisting of all multiple choice test items were used in this study. Multiple choice items in genetics and photosynthesis/ respiration were only used in this study; sample items are provided in Table 3.6.

Table 3.6: Sample Items from June 2006 New York State Living Environment Regents Examinations. Genetics and Photosynthesis/Respiration items 4, 7, and 21, respectively; Year 1

4. Hereditary information is stored inside the
- (1) ribosomes, which have chromosomes that contain many genes
 - (2) ribosomes, which have genes that contain many chromosomes
 - (3) nucleus, which has chromosomes that contain many genes
 - (4) nucleus, which has genes that contain many chromosomes
7. Hereditary traits are transmitted from generation to generation by means of
- (1) specific sequences of bases in DNA in reproductive cells
 - (2) proteins in body cells
 - (3) carbohydrates in body cells
 - (4) specific starches making up DNA in reproductive cells
21. Which process illustrates a feedback mechanism in plants?
- (1) Chloroplasts take in more nitrogen, which increases the rate of photosynthesis.
 - (2) Chloroplasts release more oxygen in response to a decreased rate of photosynthesis.
 - (3) Guard cells change the size of leaf openings, regulating the exchange of gases.
 - (4) Guard cells release oxygen from the leaf at night.
-

Table 3.7: Sample Items from June 2007 New York State Regents Examinations. Genetics and Photosynthesis/Respiration items 6, 7, and 20, respectively; Year 2

6. Which statement best explains the observation that clones produced from the same organism may not be identical?
- (1) Events in meiosis result in variation.
 - (2) Gene expression can be influenced by the environment.
 - (3) Differentiated cells have different genes.
 - (4) Half the genetic information in offspring comes from each parent.
7. A change in the base subunit sequence during DNA replication can result in
- (1) variation within an organism.
 - (2) rapid evolution of an organism.
 - (3) synthesis of antigens to protect the cell.
 - (4) recombination of genes within the cell.
20. Energy from organic molecules can be stored in ATP molecules as a direct result of the process of
- (1) cellular respiration.
 - (2) cellular reproduction.
 - (3) diffusion.
 - (4) digestion.
-

3.8.9 New York State Regents Examinations –June 2007 Questions

The 2007 Living Environment Regents examinations consisted of four parts, but only one section-Section A, the multiple choice test items were used in this study.

Traditional multiple choice items in genetics and photosynthesis/ respiration were used; sample items are provided in Table 3.7.

3.8.10 *Interviews*

Duit and Confrey (1996) suggest that student interviews help provide deeper understanding of student perceptions. Qualitative data in this study were obtained from interviews as a means to correlate and understand phenomena in context of subjectively expressing feelings without influences of others while allowing for presentation of students' understandings and the possible identification of alternative conceptions. Several types of interviews can take place during a research investigation (Oliver-Hoyo & Allen, 2006).

Burke and Demers (1979) and Kelley et al. (2003) suggest four kinds of interviewing formats exist: structured, semi-structured, non-structured, and retrospective. In a structured interview a series of questions that are prepared prior to the interview are asked and rigidly followed; these types of interviews are well controlled, reliable for consistency of responses, and are quick to conduct but limit possible novel context aspects expressed by the respondent. In a semi-structured interview, a series of questions are prepared, but the interviewer is allowed to interrupt and probe the interviewee using additional questions to gain clarity about answers given; this type of interview allows for a greater range of response outcomes but is more time laden. A non-structured interview involves open-ended questions with more probing questions to follow as a result of interviewee's responses, this is the most liberal and flexible interview type but difficult to use in comparison of subject viewpoints. Finally, the retrospective interview, used in this study, uses both structured and semi-structured approaches to conduct the interview, following the format of a verbal questionnaire. The goal is to ask questions with specific answer responses such that the information obtained can be used to compare and contrast the interview objectives while allowing for expanded views on a context specific question. Retrospective interviews involve recall by the respondent and the reconstruction of memory from prior events.

In this study, a series of interviews were held with 28 randomly selected students in the teacher researchers' advanced Living Environment classroom after school or during the students' lunch period. Students' participated in the interviews of free will and did not receive extra credit as a result of their participation. In addition to one-to-one interviews several group interviews were held where all questions were asked and answered by all student participants. The interviews were conducted approximately 10 months post course inception for both Year 1 and Year 2 (June 6 - 10, respectively) and after the completion of both units of study including post testing using all forms of assessment & achievement. The teacher researcher conducted all interviews. Sample interview questions are noted in Table 3.8.

Table 3.8: Sample Interview Questions. Interviews were post-assessment in Photosynthesis/Respiration and Genetics.

- (1) How helpful were the use of concept maps in your understanding of Photosynthesis, Respiration, and Genetics?
 - (2) Which tools (activities) used by the teacher, if any, helped you to understand the ideas tested in Photosynthesis, Respiration, and Genetics?
 - (3) Were Internet movie clips, interactive Internet web sites, concept maps, homework assignments, laboratory activities, etc. useful in your understanding of Photosynthesis, Respiration, and Genetics? What helped the most?
 - (4) Did the two-tier diagnostic (reasoning) examinations and the multiple-choice (standardized) examinations accurately assess what you know about Photosynthesis, Respiration, and Genetics?
 - (5) Which examinations do you feel best represents a test of what you know regarding Photosynthesis, Respiration, and Genetics?
-

Students were interviewed about their perceptions of which kind of examinations best measured their level of understanding of the topics of photosynthesis/respiration and genetics along with which teaching practices best assisted in student learning. Feedback from the students helped to identify methods to modify teaching techniques and the reasoning section of the diagnostic examination. Feedback could also establish if student attitude and motivation supports or negates the average scores recorded from the past-standardized, two-tier multiple choice diagnostic test, and the Living Environment Regents examinations.

3.9 Data Entry

All assessments and achievement tests were collected and stored by the teacher researcher. The data were entered into 2 Microsoft Excel spreadsheets (one spreadsheet contained data for Year 1, and the other contained data for Year 2). All students were given numerical assignments for each class over the course of the two years of study. Each student, scoring for sex (Male=1; Female=2) and paper responses were given a number which correlated with pre-TOSRA and post-TOSRA survey response sheets and achievement scoring. The standardized examinations scores from the Scantron's© in both photosynthesis/respiration and genetics were also transcribed manually into Microsoft Excel. The same format was followed for the remaining achievement measures - concept map scores, two-tier diagnostic scores for both photosynthesis/respiration and genetics, and June 2006 and June 2007 scores for both photosynthesis/respiration and genetics, Year 1 and Year 2, respectively were added to the Excel spreadsheets. Again, all scores were correlated to match the appropriate student originally keyed and numbered. All data was analyzed using SPSS version 14.

3.10 Data Entry Issues

Human error includes typographical errors. The data were entered into two different excel spread sheets, one noted as Year 1 and the other as Year 2. Students were organized with numbers and student sex was denoted as 1 for male or 2 for female. No other descriptive factors about students were collected in the Microsoft Excel sheets if not related to achievement scoring. The associations between student by name and student number became oblivious to the teacher researcher.

3.10.1 Typographical errors

Human error again, is always an issue which also includes typographical errors. The scoring as presented in the Microsoft Excel sheets were reviewed by an external person for visual errors, if any errors were detected, they were accounted for in the spreadsheet prior to data analysis.

3.10.2 Students not completing survey or examinations

With regards to TOSRA administration, if students were absent for the TOSRA survey they were not asked to use additional class time to complete the examinations therefore they were excluded for statistical analysis. In contrast, students were assigned to “make-up” any achievement exams missed but because of the nature of today’s student and due to increased technology usage, examinations were not reused after the examinations day. Students who missed the standardized examinations (photosynthesis/respiration or genetics) completed a different examination than those used in the statistical analyses. The New York State Living Environment Regents could not be repeated. One student in Year 2 absent for the Living Environment Regents had no scores analyzed from his make-up Regents’ examination.

3.10.3 Student errors

Due to language use, some students did not understand the questions they were being asked on TOSRA and the two-tier diagnostic examinations. Students may incorrectly interpret item statements on the TOSRA and on diagnostic instruments especially because this was their first opportunity to participate in either activity. Students were allowed to ask questions regarding any directions which may have confused them, if non-content related. In addition, students may have also written an incorrect response in error when they knew the factual answer.

3.10.4 Constructivist teaching issues

Constructivist teachers allow students to guide their own learning and therefore may bring ideas to the classroom that are not outlined in the Living Environment core curriculum for the topics under investigation (photosynthesis, respiration and genetics). The constructivist teacher must cover all testable material as proposed yet may be deficient of time to complete these tasks within the constructivist teaching model. The teacher may need to spend time outside of the designated 40 minutes of classroom instruction to complete associated activities for enhancement of student learning. The level of understanding of instructed concepts and their assessment on statewide assessments vs. previously validated two-tier multiple choice diagnostic

tests may widely differ because the level of testing is vastly different. The aim of the advanced Living Environment course as designed by the Board of Regents and the concepts taught by a constructivist teacher for the respective levels tested, should mirror one another but may not in this case.

3.11 Data Analysis

All data were analyzed using SPSS version 14. The TOSRA data was analyzed for internal reliability and validity of the seven scales of science attitudes. The Cronbach (1951) alpha coefficient was used to measure reliability while ANOVA was used to check the test's validity. The Pearson r was used to find correlations between the seven scales of science attitudes.

The TOSRA responses were also used to determine attitude changes after 10 months of constructivist teachings. This was reviewed using paired sample t-test to check for significant differences between the pre-test and post-test scores. Several experimental studies have used similar comparisons when trying to determine changes in attitudes after a particular intervention.

The standardized examinations, concept maps, two-tier multiple choice diagnostic tests, and the Living Environment Regents were also analyzed using SPSS version 14. The reliability of the conceptual tests was determined by Cronbach (1951) alpha coefficient reliability. Validity was determined by experts' assessment. One way ANOVA was conducted between the content assessment of both standardized and diagnostic test items.

3.11.1 Descriptive statistics

Descriptive statistics were used to compare the outcomes from the quantitative data collected with regards to the research questions outlined in Section 3.3. The past-standardized Living Environment questions in photosynthesis/respiration and genetics, were analyzed against the two-tier diagnostic examinations, final concept map scores, and Living Environment Regents scores (Year 1 & Year 2) to determine

which examinations students best scored and consequentially best assessed achievement by NYS standards and student standards as described in interviews.

Measures of central tendency were used to support outcomes of the research questions outlined in Section 3.3 for learning and teaching in the advanced Living Environment classes in this Long Island, NY high school. The pre-TOSRA and post-TOSRA data along with student interviews for similarity of response frequency distribution between qualitative and quantitative assessments will be described in Chapter 4. In addition, quantitative assessment measures of central tendency (mode, median, and mode) and measure of spread (variance and standard deviation) parameters for all achievement examinations are described in tables, charts, and graphs in Chapter 4.

3.11.2 Inferential statistics and correlations between variables

Students in New York are mandated to pass (grade of 65 or greater) the Living Environment Regents in order to graduate from high school. The population sampled in this study, emulates a small group of the overall population with which the outcomes of this study are reflective. Yet, the Living Environment Core Curriculum (as a teaching guide) and changing teaching practices to encourage learning (associations with Annual Professional Performance Reviews and pressure from governmental/school administrative bodies) suggest this study sample does represent the larger population of students discussed in Chapter 5 conclusions. Statistical significance was determined with a minimum alpha value of .05 for all statistical tests, such that stated outcomes are not resultant of random chance as a means to infer generalities about the larger population not directly studied.

3.11.3 Triangulation of qualitative and quantitative data

Qualitative data in the form of interviews, initial concept map corrective assessments and the TOSRA surveys were used to establish student relationships between what was taught in the classroom and what the students actually perceived as taught and learned in their classroom environment (Oliver-Hoyo & Allen, 2006). Qualitative data may help determine differences in assessment scores in relationship with

subjective techniques and student attitudes towards science or teaching techniques as compared to objective activities such as standardized achievement examinations (Oliver-Hoyo & Allen, 2006).

Quantitative data in the form of past-standardized Living Environment test questions in photosynthesis/respiration and genetics were analyzed against the two-tier multiple choice diagnostic examinations, final concept map, and Living Environment Regents performances to determine if the scores students received as achievement measures actually assessed student learning suitably. The examinations showing the greatest achievement score outcomes should match concept map scores and student interview comments with regards to perceived learning and understanding by the students tested in this study.

Drawing conclusions from a wide range of assessments and achievement measures is challenging. Triangulation of two sets of data, in this study, may assist in determining which examinations best measure understanding and achievement. Triangulation of multiple aspects of data collection should yield a more accurate and valid estimate of student outcomes based upon constructivist teaching and achievement examinations. Validation of qualitative and quantitative data was compared against several data collection methods.

A dual triangulation method was used in this study. The dual triangulation scheme included qualitative data and quantitative data collected (concept map scoring was deemed subjective) to compare outcomes against all quantitative data collected. The TOSRA surveys, interviews, and pre-achievement concept maps were used in the first triangulation scheme to compare outcomes. The second triangulation scheme compared past-standardized examinations, diagnostic examinations, post-assessment concept maps, and the Living Environment Regents scores against one another. The two triangulation sets were then assessed for all outcomes against opposite methods of data collection. When data from three methods, per triangulation scheme, indicated the same results, then greater validity existed in the conclusions drawn. This data would then be compared in the same manner to the data collected in the second triangulation scheme. Triangulation was used as a measure of success to

address each specific research question asked in Section 3.3 and to depict which methods best assessed learning and achievement collectively, in this study.

3.12 Summary

Multiple qualitative and quantitative assessments were completed in this study because a more exacting measure of student learning and achievement in New York State and the United States is needed. The study was conducted over two consecutive years to increase the sample size for a more representative population of students who will take the NYS Living Environment Regents examinations. The TOSRA was used in this study because it provided a good overview of student attitudes towards science. The reliability and validity of this instrument has been demonstrated for several decades. The qualitative data via interviews was collected to support the outcomes of the quantitative data which included the collaboration of several tests including the use of the TOSRA, concept maps, constructivist teaching methods to compare against levels of understanding assessed when using past-standardized tests and the NYS Living Environment Regents versus two-tier multiple choice diagnostic tests. In conclusion, the results and conclusions obtained by analyses are examined in Chapter 4 and Chapter 5, respectively.

Chapter 4

RESEARCH FINDINGS

4.1 Introduction and Overview of Chapter

The purpose of this chapter is to report the findings resultant of data analyzed in this study. This chapter discusses the TOSRA in terms of reliability and validity along with the concept maps, interviews, standardized exams, two-tier diagnostic exams, and the NYS Living Environment Regents to address the eleven research questions. This study evaluated multiple achievement exams for ability (coupled with constructivist teaching approaches) to assess student learning. Further, the use of diagnostic tests, standardized tests, and the Living Environment Regents in photosynthesis & respiration and genetics as a measure of achievement with student perceptions based upon their attitudes towards science (TOSRA) and interviews assessed the inadequacies of the New York State Living Environment Regents exam to measure student knowledge over a course of instruction, specifically advanced students.

Section 4.1 presented the chapter overview and the following sections present overviews of data analyses for data collected in this study. The next section presents the first research question on concept maps (Section 4.2), quantitative analysis using descriptive statistics to review the reliability of TOSRA and achievement measures to address the study's research questions inferential statistics (Section 4.3), quantitative data using reliabilities, correlations, and inferential statistics (Section 4.4), qualitative data from student interviews to address assessments and achievement measures (Section 4.5), dual triangulation of all data is addressed (Section 4.6), and the chapter closes with the summary of all research question outcomes (Section 4.7).

In order to reduce the spacing of information within the data tables several abbreviated terms were used to describe the instruments used with the examination

of achievement. Table 4.1 contains the collection of abridged terminology used throughout Chapter 4 and Chapter 5 of this study.

Table 4.1: Key for Abridged Terminology.

Abbreviated Term	Completely Named Termed
P/R	Photosynthesis/Respiration
G	Genetics
P/R/G	Photosynthesis/Respiration/Genetics
Std [test]	Standardized Multiple Choice Examination (circa 1989-2002)
Diagnostic MC	Two-Tier Multiple Choice Diagnostic Examination
LER	Living Environment Regents (Year 1 or Year 2)
Total	Denotes an entire exam as expertly scored

4.2 Descriptive and Inferential Statistics for all Tests to compare attitudes and achievement with gender

The first analysis in this study dealt with quantitative analysis of data based upon the outlined research questions, introduced in Chapter 1. The first quantitative data arose from assessments of student knowledge through concept maps, then scoring final concept maps in photosynthesis/ respiration and genetics for Year 1 & Year 2 students. The analysis of student attitudes towards science was compared against pretest and posttest outcomes for all seven scales of *Test of Science Related Attitudes* (TOSRA). The research questions were grouped according to descriptive statistics for total differences and gender differences as a means of understanding the role of student attitudes towards science for all Year 1 and Year 2 student samples. An overview of Year 1 and Year 2 data for comparative analysis are discussed as outlined in research questions 1a, 1b and 1c, respectively.

1a. What are the Cronbach alpha reliability measures and the mean correlations with other scales for the *Test of Science Related Attitudes*?

The internal consistency reliability (Cronbach alpha coefficient) for each TOSRA scale was calculated for two units of analysis (pretest and posttest scales means) for the Year 1 and Year 2 sample of 155 students in 6 classes. As shown in Table 4.2, there was a range of the Cronbach-alpha reliabilities from 0.61 (Year 2; Normality of

Scientists, an outlier) and 0.71 to 0.96 for all pretest scales. The highest pre-test Cronbach alpha value was 0.96 for Career Interest in Science (Year 1). The posttests for both Year 1 and Year 2 showed there was a range of the Cronbach-alpha reliabilities from 0.42 and 0.59 specifically for Adoption of Scientific Attitudes while all other scales ranged from 0.75 to 0.93. Enjoyment of Science Lessons (Year 2) showed the highest post-test Cronbach alpha value. The Normality of Scientist scale, pretest-Year 2, low reliability value of 0.61 and the low reliability value of 0.42 and 0.59 for Adoption of Scientific Attitudes in Year 1 and Year 2 respectively are very low, therefore discussion of the analysis of these scales should be approached with caution (Table 4.2).

Table 4.2: TOSRA Internal Consistency Reliability (Cronbach’s Alpha Coefficient) and Discriminant Validity (Mean Correlation with Other Scales) for Year 1 (N = 75) & Year 2 (N = 80) Pretest and Posttest Scales Means.

Scale	Cronbach’s Alpha Reliability				Mean Correlations with Other Scales			
	Year 1		Year 2		Year 1		Year 2	
	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest
Social Implications of Science	0.84	0.79	0.79	0.76	0.59	0.42	0.38	0.33
Normality of Scientists	0.83	0.76	0.61	0.84	0.41	0.33	0.14	0.26
Attitude to Scientific Inquiry	0.91	0.75	0.90	0.92	0.49	0.42	0.33	0.37
Adoption of Scientific Attitudes	0.75	0.59	0.71	0.42	0.61	0.48	0.43	0.31
Enjoyment of Science Lessons	0.95	0.89	0.91	0.93	0.66	0.55	0.44	0.53
Leisure Interest in Science	0.81	0.85	0.90	0.90	0.62	0.41	0.46	0.47
Career Interest in Science	0.96	0.86	0.91	0.92	0.65	0.55	0.44	0.46

1b. What is the correlation between scales for student responses on pre- and post-tests of the *Test of Science Related Attitudes*?

The empirical independence of conceptually-distinct scales or discriminant validity was examined for the TOSRA to ensure each scale measured a unique aspect of the students' attitudes towards science. The mean correlation of each scale with another scale ranged from 0.14 (pre-test Year 2; Normality of Scientists, an outlier) and 0.33 to 0.66 for all pretest scales as the unit of analysis and from 0.26 (Year 2; Normality of Scientists, an outlier) and 0.31 to 0.55 for all posttest scales as the unit of analysis (Table 4.2).

1c. Are there any differences between pre-and post-tests for all students on the *Test of Science Related Attitudes (TOSRA), Year 1 & Year 2*?

Responses to the seven TOSRA scales shown in Table 4.3 reveal statistically significant changes in student attitudes for every scale except Attitude to Scientific Inquiry for both Year 1 and Year 2 pre testing to post testing. Year 2 exhibited increased agreement towards positive attitudes for all scales. Overall, the students from pretest to posttest displayed distinct differences in attitudes towards science, based upon 10 months of instruction.

The data suggests significant changes occurred in student attitudes during Year 2 but no significant changes occurred with regards to average means of the scales for Year 1. It is important to note the Year 1 students were asked to complete the post-test TOSRA at the close of the 3-hour, Living Environment Regents examination. At this point students may have been eager to leave the testing facility and did not complete the item answering to the best of their ability. Sample graphical illustrations of pretest/posttest data are found in Figures 4.1 and 4.2. Discussion of the analyses obtained from Year 1 TOSRA posttest must be considered with caution (see Table 4.3). Full graphical illustrations of TOSRA pretest/posttest outcomes can be found in Appendix IX.

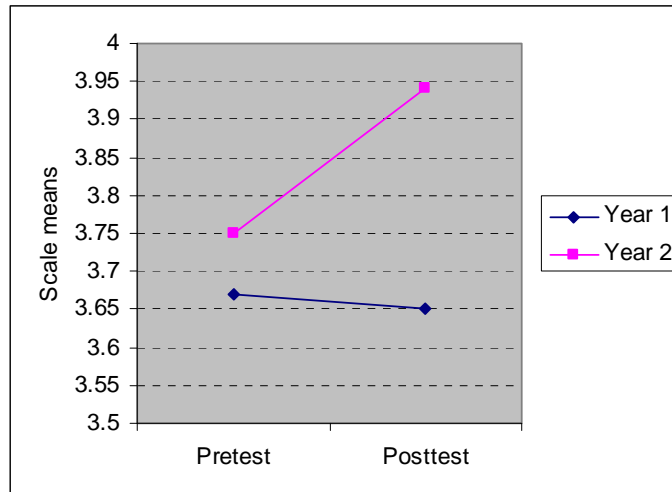


Figure 4.1: TOSRA Social Implications of Science scale (S; Years 1 & 2 pretest-posttest differences).

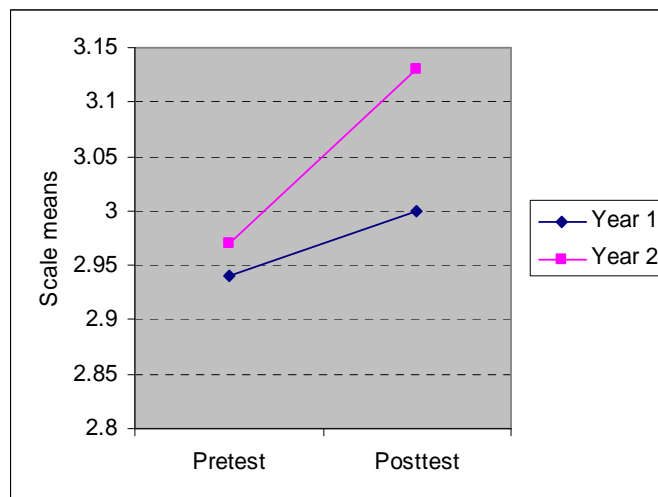


Figure 4.2: TOSRA Career Interest in Science scale (S; Years 1 & 2 pretest-posttest differences).

Table 4.3: TOSRA Year 1 (N = 75) and Year 2 (N = 80) Scales Means.

Scales	Average Means				Average SD				<i>t</i> value	
	Year 1		Year 2		Year 1		Year 2		Year 1	Year 2
	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest		
Social Implications of Science	3.67	3.65	3.75	3.94	0.50	0.53	0.48	0.52	0.36	3.49**
Normality of Scientists	3.47	3.57	3.49	3.61	0.51	0.50	0.38	0.52	1.84	2.14*
Attitude to Scientific Inquiry	3.62	3.45	3.61	3.63	0.76	0.77	0.72	0.71	1.85	0.35
Adoption of Scientific Attitudes	3.56	3.51	3.64	3.83	0.49	0.42	0.48	0.66	0.91	2.57*
Enjoyment of Science Lessons	3.17	3.21	3.43	3.66	0.86	0.51	0.69	0.76	0.51	2.74**
Leisure Interest in Science	2.45	2.55	2.56	2.82	0.85	0.71	0.85	0.80	1.37	3.41**
Career Interest in Science	2.94	3.00	2.97	3.13	0.95	0.71	0.75	0.77	1.06	2.04*

* $p < 0.05$, ** $p < 0.01$

- 1d. Are there any differences between pre- and post-tests responses for males and females on the *Test of Science Related Attitudes, Year 1 & Year 2*?

Table 4.4 shows the most significant change in Year 1 for males ($p < 0.01$) and for females (slightly significant at $p = 0.06$) is the Attitude toward Scientific Inquiry post instruction. There was a significant improvement in the mean score of males 3.73 to 3.45 and a weak improvement in female attitudes towards scientific inquiry 3.47 to 3.20. Leisure Interest in Science significantly decreased in males 2.60 to 2.49 as compared to females who showed an insignificant increase 2.48 to 2.63 while Social Implications of Science slightly improved in males 3.58 to 3.73. Limited variations in the mean response of all scales were seen between males or females pretest to post testing of the TOSRA during Year 1.

Table 4.4: TOSRA Scales Means Pretest and Posttest Gender Comparison- Year 1 (N=75)

Scales	Average means				Average SD				t value	
	Males		Females		Males		Females		Males	Females
	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest	Pretest	Post test		
Social Implications of Science	3.58	3.73	3.64	3.56	0.48	0.45	0.58	0.62	1.95~	0.79
Normality of Scientists	3.48	3.60	3.45	3.39	0.48	0.45	0.56	0.48	1.57	0.79
Attitude to Scientific Inquiry	3.73	3.45	3.47	3.20	0.63	0.63	0.90	0.47	3.11**	1.76 ~
Adoption of Scientific Attitudes	3.63	3.64	3.47	3.34	0.42	0.37	0.56	0.44	0.08	1.18
Enjoyment of Science Lessons	3.20	3.27	3.14	3.14	0.85	0.81	0.89	0.69	0.83	0.04
Leisure Interest in Science	2.60	2.49	2.48	2.63	0.69	0.75	0.71	0.69	2.06*	1.34
Career Interest in Science	3.10	3.14	2.72	2.84	0.93	0.76	0.94	0.62	0.47	0.96

~p<0.06, ~p<0.051, *p<0.05, **p<0.01

The analysis of pretest and posttest outcomes of the seven scales of *Test of Science Related Attitudes* (TOSRA) in Year 2 showed highly significant changes for males and females in two scales, the Social Implications of Science and Leisure Interest in Science post instruction (see Table 4.5). There was a significant improvement in males towards Social Implications of Science 3.67 to 3.92 ($p < 0.01$) and an insignificant increase in female attitudes 3.86 to 3.96. Leisure Interest in Science for males' increased dramatically from 2.48 to 2.77 with a minor increase in females from 2.66 to 2.89. In addition, Adoption of Scientific Attitudes and Enjoyment of Science Lessons for males significantly increased from 3.60 to 3.88 and 3.43 to 3.70 with slight increases on both scales denoted by females, respectively. All scales with the exception of Normality of Scientists, Attitude to Scientific Inquiry, and Career Interest in Science showed significant changes in attitudes in males with slight increases by females.

Table 4.5: TOSRA Scales Means Pretest-Posttest Gender Comparisons –Year 2 (N = 80)

Scales	Average means				Average SD				<i>t</i> value	
	Males		Females		Males		Females		Males	Females
	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest		
Social Implications of Science	3.67	3.92	3.86	3.96	0.44	0.46	0.52	0.60	3.48**	1.29
Normality of Scientists	3.53	3.68	3.44	3.52	0.32	0.51	0.44	0.51	1.75	1.23
Attitude to Scientific Inquiry	3.63	3.63	3.58	3.63	0.70	0.64	0.75	0.81	0.01	0.55
Adoption of Scientific Attitudes	3.60	3.88	3.70	3.76	0.49	0.73	0.46	0.55	2.57*	0.70
Enjoyment of Science Lessons	3.43	3.70	3.43	3.61	0.71	0.74	0.67	0.79	2.50*	1.34
Leisure Interest in Science	2.48	2.77	2.66	2.89	0.90	0.85	0.77	0.74	2.82**	1.92
Career Interest in Science	2.96	3.13	3.00	3.13	0.80	0.83	0.69	0.70	1.72	1.11

* $p < 0.05$, ** $p < 0.01$

Particularly, the mean scores of the pretest and posttest of the TOSRA scales (N=7) showed minor statically significant differences for females but wider ranges of significance for males. In Year 1, significant differences were identified regarding gender for Social Implications of Science and Leisure Interest in Science. Social Implications of Science mean score for males increased while female mean scores decreased. In addition, Leisure Interest in Science mean score decreased in males but increased in females. During Year 2 a wider change in mean scores on seven TOSRA scales occurred when comparing males and females. Several shifts in responses occurred when comparing mean scores of males and females for the following scales: Attitude of Science Inquiry, Adoption of Scientific Attitudes, Enjoyment of Science Lessons and Career Interest in Science, Year 2. Only Normality of Scientists showed no differences in either Year 1 or Year 2 (see italicized vs. bolded text in Table 4.6).

Table 4.6: Overview of TOSRA Consistencies or Variations between Year 1 and Year 2 via gender. M= Male; F=Female

Scales	Year 1		Year 2	
	Pre-test	Post-test	Pre-test	Post-test
Social Implications of Science	M<F	M>F	M<F	M<F
Normality of Scientists	M>F	M>F	M>F	M>F
Attitude to Scientific Inquiry	M>F	M>F	M>F	M=F
Adoption of Scientific Attitudes	M>F	M>F	M<F	M>F
Enjoyment of Science Lessons	M>F	M>F	M=F	M>F
Leisure Interest in Science	M>F	M<F	M<F	M<F
Career Interest in Science	M>F	M>F	M<F	M=F

Comparisons between gender based pretest and posttest Year 1 and Year 2 TOSRA comparisons, illustrated graphically, are shown in Figures 4.3 & 4.4 and 4.5 & 4.6 (Year 1 vs. 2; Attitude to Scientific Inquiry and Career Interest in Science; Year 1 & 2 pretest-posttest comparisons). Overall, the students from year to year displayed unique differences in attitudes towards science, full graphical illustrations of TOSRA (N=7) pretest/posttest outcomes can be found in Appendix X.

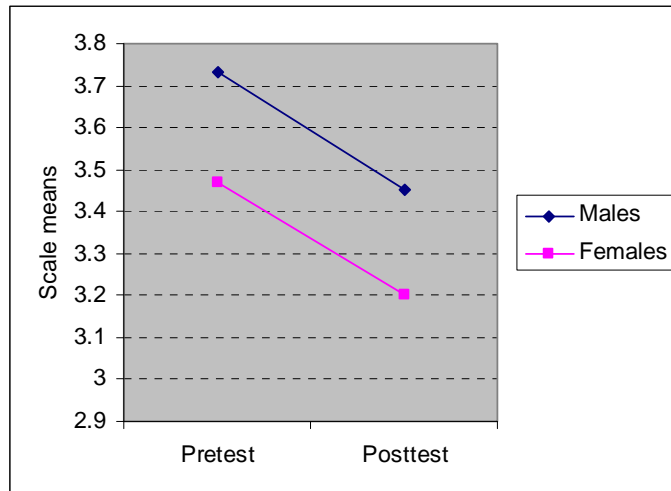


Figure 4.3: TOSRA Attitude to Scientific Inquiry scale (Year 1 pretest-posttest gender differences).

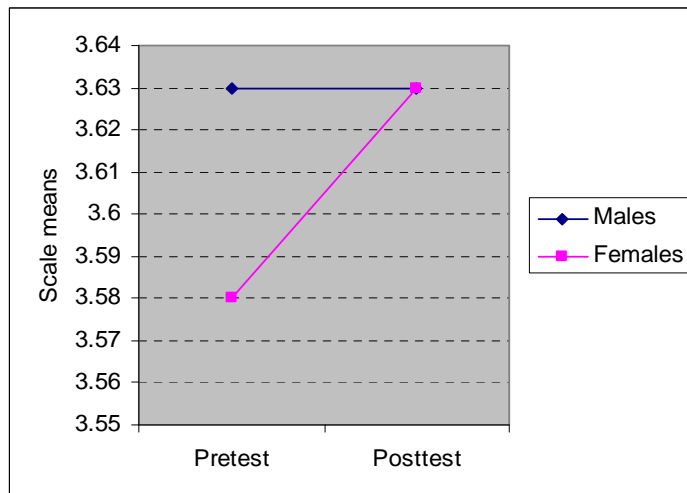


Figure 4.4: TOSRA Attitude to Scientific Inquiry scale (Year 2 pretest-posttest gender differences).

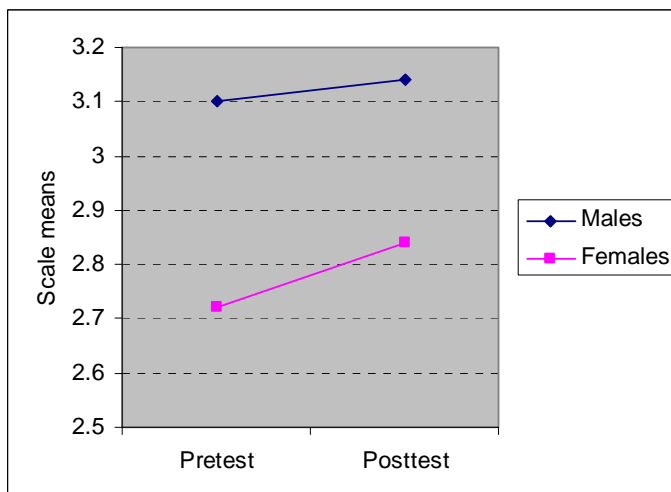


Figure 4.5: TOSRA Career Interest in Science scale (Year 1 pretest-posttest gender differences).

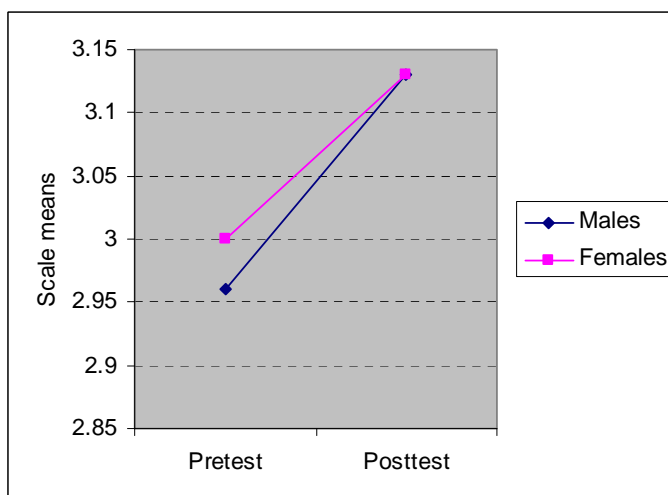


Figure 4.6: TOSRA Career Interest in Science scale (Year 2 pretest-posttest gender differences).

- 1e. What are the Cronbach alpha reliability measures and the mean correlations with past-standardized multiple choice examinations, the two-tier diagnostic examinations and the Living Environment Regents examination in photosynthesis/respiration and genetics, Year 1 & Year 2, respectively?

The components of this study used to measure achievement in photosynthesis/respiration and genetics after the instructional periods were past-standardized multiple choice examinations, the two-tier diagnostic examinations and

the Living Environment Regents examination in photosynthesis/respiration and genetics, Year 1 & Year 2, respectively. As shown in Tables 4.7 and 4.8 there was a wide range between total percentage correct for past-standardized multiple choice examinations, the two-tier diagnostic examinations and the Living Environment Regents examination to compare outcomes of achievement as posed in the research question.

Table 4.7: Summary of Descriptive Statistics for all comparison of Tests- Year 1 (N=81)

Source of data	Reliability	Maximum possible score	Mean Correct	Standard deviation	Total % Correct
<i>Photosynthesis/Respiration</i>					
Concept Maps		10			
Total Std test	0.98	45	39.19	3.27	87
Total Diagnostic	0.73	15	8.78	2.72	59
MC Total LER	0.23	5	4.15	0.97	83
<i>Genetics</i>					
Concept Maps		10	6.00	2.64	60
Total Genetics Std test	0.97	50	41.61	4.10	83
Total Diagnostic MC	0.51	14	9.57	1.92	68
Total LER Genetics	0.32	10	7.62	1.68	76

Table 4.8: Summary of Descriptive Statistics for all comparison of Tests- Year 2 (N=82)

Source of data	Reliability	Maximum possible score	Mean Correct	Standard deviation	Total % Correct
<i>Photosynthesis/Respiration</i>					
Total Std test	0.97	35	21.02	10.98	60
Total Diagnostic	0.77	15	9.84	3.05	65
MC Total LER	-	3	2.72	.50	91
<i>Genetics</i>					
Concept Maps		15	11.99	2.43	80
Total Genetics Std test	0.66	50	44.18	3.63	88
Total Diagnostic MC	0.37	14	9.07	1.71	65
Total LER Genetics	0.25	10	8.55	1.20	86

The reliability value for the past standardized tests using previous Regents examinations and AP Biology College Board test items was 0.98 and 0.97, respectively for Year 1 and Year 2 in photosynthesis/respiration while 0.97 and 0.66 reliability were noted for the genetics examinations in Year 1 and Year 2, respectively. The reliability values for the LER in both photosynthesis/respiration and genetics were below 0.32 with a negative reliability found in Year 2 LER for photosynthesis. The outcomes may be correlated to the low number of items present on the examination. The diagnostic examinations reliabilities in photosynthesis/respiration were 0.73 and 0.77, Year 1 and 0.51 and 0.37, Year 2 for genetics. The lower genetics reliability may be due to lack of validated items added by the teacher researcher based upon concept map assessments.

Students in the six classes scored high on the past Living Environment Regents examinations involving items assessing photosynthesis/respiration (mean = 83% and 91%; Year 1 and Year 2) with a small range from 76-100% representing this test. However, on the diagnostic tests assessing the same concepts in genetics, the mean scores were much lower (mean = 59% and 65%; Year 1 and Year 2) with a much wider range. Of note is that the students who scored highest on the Regents exam items (100%) also scored highest on the diagnostic tests indicating that the Regents examination did not assess the full academic conceptual understanding of these students.

The second set of quantitative data arose from correlations of assessments of student knowledge through achievement examinations (past-standardized multiple choice examinations, the two-tier diagnostic examinations and the Living Environment Regents examinations) and final concept maps in genetics for Year 1 & Year 2 students. The second analysis in this study dealt with quantitative analysis of data based upon the outlined research questions 7-12, introduced in Chapter 1.

If. How do student responses compare on past-standardized multiple choice examinations, the two-tier diagnostic examinations and the Living Environment Regents examination in photosynthesis/respiration and genetics, Year 1 & Year 2, respectively?

The components of this study used to measure achievement in photosynthesis/respiration and genetic after a period of instruction were past-standardized multiple choice examinations, the two-tier diagnostic examinations and the Living Environment Regents examination, concept maps (genetics topic only for correlations due to one year of not recording photosynthesis/respiration concept map scores) in Year 1 & Year 2, respectively.

Table 4.9 presents the linear relationships between all assessments using Pearson's correlation. No correlation between the Living Environment Regents examination and the in-class past-standardized examination consisting of all multiple choice items (which included AP Biology test items from the Rules Wizard©) occurred. Correlations between two-tier multiple choice diagnostic test and past standardized examination questions did significantly exist at $p < 0.01$ in P/R in Year 1.

Table 4.9: Pearson Correlation Coefficients for Year 1 Students' Performance for Photosynthesis and Respiration Concepts (N = 81). Correlating Living Environment Regents items, two-tier Multiple Choice Diagnostic test items and Past- Standardized test items.

	Living Environment Regents Test	Multiple-choice Diagnostic Test	Past-Standardized Test
Living Environment Regents Test		0.01	0.16
Multiple-choice Diagnostic Test		-	0.40**
Past Standardized Test		-	-

** $p < 0.01$

No correlation between the Living Environment Regents examination and two-tiered multiple choice diagnostic test existed (Table 4.10) in genetics during Year 1. Yet, the past-standardized test showed a correlation with all of the achievements (containing AP Biology questions from the Rules Wizard©) including the two-tier multiple choice diagnostic examinations and the Living Environment Regents examinations. No correlation was seen between the two tier multiple choice test and the concept maps. In light of the data presented in Table 4.10, the original thesis idea

was supported: LER tests and two-tier multiple choice diagnostic tests do not correlate in advanced students.

Table 4.10: Pearson Correlation Coefficients for Year 1 Students' Performance for Genetics Concepts (N = 81). Correlating Living Environment Regents items, two-tier Multiple Choice Diagnostic test items, concept maps and Past- Standardized test items.

	Living Environment Regents Test	Multiple-choice Diagnostic Test	Concept Maps	Standardized Test
Living Environment Regents Test		0.18	0.27*	0.33**
Multiple-choice Diagnostic Test		-	0.29*	0.46**
Concept Maps		-	-	0.30**
Standardized Test		-	-	-

** $p < 0.01$ * $p < 0.05$

Table 4.11 showed no correlation between the Living Environment Regents examination and two-tiered multiple choice diagnostic test or past-standardized test in P/R in Year 2. The past-standardized test (containing AP Biology questions from the Rules Wizard©) showed a highly significant correlation with two-tier multiple choice diagnostic examinations ($p < 0.01$). No correlation was seen between the two tier multiple choice test and the Living Environment Regents examination. This again supports the original thesis idea that the LER tests and two-tier multiple choice diagnostic tests do not correlate in advanced students.

Table 4.11: Pearson Correlation Coefficients for Year 2 Students' Performance for Photosynthesis/Respiration Concepts (N = 82). Correlating Living Environment Regents items, two-tier Multiple Choice Diagnostic test items and Past- Standardized test items.

	Living Environment Regents Test	Multiple-choice Diagnostic Test	Standardized Test
Living Environment Regents Test		0.01	0.04
Multiple-choice Diagnostic Test		-	0.33**
Standardized Test			

** $p < 0.01$

Table 4.12 showed no correlation between the Living Environment Regents examination and the two-tiered multiple choice diagnostic test or concept maps in genetics for Year 2. This again supports the original thesis idea that the LER tests and two-tier multiple choice diagnostic tests do not correlate for advanced students. The past-standardized test (containing AP Biology questions from the Rules Wizard©) showed a highly significant correlation with the two-tier multiple choice diagnostic examinations and a significant correlation with concept maps ($p < 0.01$).

Table 4.12: Pearson Correlation Coefficients for Year 2 Students' Performance for Genetics Concepts (N = 82). Correlating Living Environment Regents items, two-tier Multiple Choice Diagnostic test items, concept maps and Past- Standardized test items.

	Living Environment Regents Test	Multiple-choice Diagnostic Test	Concept Maps	Standardized Test
Living Environment Regents Test		0.20	0.05	0.12
Multiple-choice Diagnostic Test		-	0.09	0.42**
Concept Maps		-	-	0.22*
Standardized Test		-	-	-

** $p < 0.01$ * $p < 0.05$

4.3 Influence of Gender on Conceptual Understanding via Achievement Scores

- 2a. What is the correlation between gender and total assessment outcomes and understandings of photosynthesis and respiration and genetics on past-standardized multiple choice examinations, the two-tier diagnostic examinations, concept maps and the NYS Living Environment Regents (Year 1)?

In Year 1, no statistically significant differences between males and females existed with regards to overall performance on all achievement measures. Cohen's *d* values for all assessment measures in photosynthesis/respiration and genetics ranged between 0.13–0.38. The Living Environment Regents examination for photosynthesis/respiration items possibly favored females understanding slightly over males as denoted by slightly larger average mean (4.37) for females when compared to males (4.05) while also holding true for the past-standardized multiple choice examinations and the two-tier diagnostic. The converse was seen in genetics; the Living Environment Regents examination for genetics items possibly favored males understanding slightly over females as denoted by slightly larger average mean (7.95) for males when compared to females (7.45) as outlined in Table 4.13. In genetics, males outscored the girls in all measures but no significant difference was denoted in the items to cause the differences. Most Cohen's *d* showed less than 2 (with the exception of the Living Environment Regents – showed a Cohen's *d* of 0.38 for photosynthesis/respiration and 0.34 for genetics) therefore minimal differences between the students ability to score well on specified items in for all other measures was noted (see Table 4.13).

Table 4.13: Year 1 Students' Performance in Assessments. Differences between Males (N = 43) and Females (N = 38)

Assessments	Items Max. Score	Average Means		Average SD		F values	Cohen's <i>d</i>
		Male	Female	Male	Female		
<i>Photosynthesis and Respiration</i>							
Standardized Test	45	38.73	39.67	3.75	2.67	1.51	0.29
Multiple- choice Diagnostic Test	14	8.95	9.32	2.91	2.65	0.34	0.13
Living Environments Regents Test	5	4.05	4.37	0.90	0.79	2.91	0.38
<i>Genetics</i>							
Concept Maps	10	7.06	6.66	3.40	2.26	0.38	0.14
Standardized Test	50	41.31	41.95	4.76	3.25	0.48	0.16
Multiple- choice Diagnostic Test	15	9.47	9.18	1.71	1.92	0.49	0.16
Living Environments Regents Test	10	7.95	7.45	1.38	1.52	2.47	0.34

(Effect size of $d = 0.2$ is small, $d = 0.5$ is medium and $d = 0.8$ is large)

2b. What is the correlation between gender and total assessment outcomes understandings of photosynthesis and respiration and genetics on past-standardized multiple choice examinations, the two-tier diagnostic examinations, concept maps and the NYS Living Environment Regents (Year 2)?

In Year 2, again no statistically significant differences between males and females existed with regards to overall performance on all achievement measures. Cohen's d values for all assessment measures in photosynthesis/ respiration and genetics ranged between 0.10 - 0.37. The past-standardized test for photosynthesis/respiration items possibly favored females understanding slightly over males as denoted by slightly

larger average mean (30.91) for females when compared to males (29.64) while also holding true for the Living Environment Regents examination, 3.36 to 3.16 respectively. The converse was seen in genetics; the concept maps for genetics items possibly favored males understanding slightly over females as denoted by slightly larger average mean (12.39) for males when compared to females (11.46) as outlined in Table 4.14. In genetics males outscored the females average means in past standardized test by 0.02 and the two-tier multiple choice diagnostic examination by 0.24 but no significant difference is denoted in the items to cause the differences. Most Cohen's d showed less than 2 (with the exception of the past standardized test showed a Cohen's d of 0.34; photosynthesis/respiration and the concept maps showed a Cohen's d of 0.37; genetics) therefore minimal differences between the students' ability to score on specified items for all other measures was noted.

Table 4.14: Year 2 Students' Performance in Assessments. Differences between Males (N = 43) and Females (N = 39)

Assessments	Items Max. Score	Average Means		Average SD		F values	Cohen's d
		Male	Female	Male	Female		
<i>Photosynthesis and Respiration</i>							
Standardized Test	35	29.64	30.91	4.62	2.73	2.12	0.34
Multiple-choice Diagnostic Test	15	9.86	9.54	2.97	3.20	0.22	0.10
Living Environments Regents Test	4	2.95	3.00	0.79	0.67	1.47	0.27
<i>Genetics</i>							
Concept Maps	15	12.39	11.46	1.77	3.05	3.06	0.37
Standardized Test	50	44.02	44.40	3.72	3.54	0.22	0.10
Multiple-choice Diagnostic Test	14	8.93	8.69	1.86	1.94	0.32	0.13
Living Environments Regents Test	12	3.16	3.36	0.58	0.69	0.11	0.08

(Effect size of $d = 0.2$ is small, $d = 0.5$ is medium and $d = 0.8$ is large)

2c. Does a correlation exist between first tier and second tier responses on the diagnostic examinations in photosynthesis/ respiration (Year 1 and Year 2)?

Tables 4.15 and 4.16 compare the outcomes between all two-tier multiple choice questions in photosynthesis/respiration in Year 1 and Year 2. For each item, the student sample would score higher if only the first tier was considered for the 163 students who completed the examinations. Year 1 students scored approximately 11% higher (Table 4.15) and Year 2 students scored approximately 10% higher (Table 4.16) on the first tier P/R items over the combined tiers.

Table 4.15: Percentage (%) of Correct Responses to Year 1 Photosynthesis and Respiration Two-tier Multiple-choice Items (N = 81)

Item no.	Tier 1 Only	Combined tiers	Item no.	Tier 1 Only	Combined tiers
1	97.5	18.5	2	40.7	30.9
3	48.1	39.5	4	96.3	93.8
5	60.5	58.0	6	98.8	95.1
7	33.3	32.1	8	74.1	70.4
9	40.7	25.9	10	82.7	75.3
11	93.8	91.4	12	50.6	50.6
13	65.4	63.0	14	100	95.1
15	97.5	72.8			

Table 4.16: Percentage (%) of Correct Responses to Year 2 Photosynthesis and Respiration Two-tier Multiple-choice Items (N = 82)

Item no.	Tier Only	Combined tiers	Item no.	Tier 1 Only	Combined tiers
1	98.8	24.4	2	43.9	30.5
3	59.8	48.8	4	98.8	97.6
5	76.8	75.6	6	96.3	95.1
7	54.9	52.4	8	84.1	78.0
9	63.4	42.7	10	67.1	52.4
11	92.7	90.2	12	59.8	57.3
13	76.8	65.9	14	98.8	91.5
15	96.3	68.3			

2d. Does a correlation exist between first tier and second tier responses on the diagnostic examinations in genetics (Year 1 and Year 2)?

Tables 4.17 and 4.18 compare the outcomes between all two-tier multiple choice questions in genetics in Year 1 and Year 2. For each item, the student sample would score higher if only the first tier was considered for the 163 students who completed the examinations. Year 1 students scored approximately 19% higher (Table 4.17) and Year 2 students scored approximately 19% higher (Table 4.18) on the first tier P/R items over the combined tiers.

Table 4.17: Percentage (%) of Correct Responses to Year 1 Genetics Two-tier Multiple-choice Items (N = 81)

Item no.	Tier 1 Only	Combined tiers	Item no.	Tier 1 Only	Combined tiers
1	95.1	95.1	2	96.3	84.0
3	34.6	27.2	4	87.7	85.2
5	97.5	93.8	6	100	98.8
7	72.8	28.4	8	100	87.7
9	84.0	69.1	10	96.3	70.4
11	77.8	25.9	12	40.7	23.5
13	93.8	91.4	14	76.5	76.5

Table 4.18: Percentage (%) of Correct Responses to Year 2 Genetics Two-tier Multiple-choice Items (N = 82)

Item no.	Tier 1 Only	Combined tiers	Item no.	Tier 1 Only	Combined tiers
1	96.3	95.1	2	87.8	64.6
3	32.9	32.9	4	95.1	85.4
5	98.8	90.2	6	98.8	97.6
7	81.7	24.4	8	100	75.6
9	81.7	58.5	10	90.2	31.7
11	70.7	29.3	12	34.1	17.1
13	95.1	93.7	14	86.6	85.4

4.4 Qualitative and Quantitative Data Triangulation to measure Understanding

3a. How do concept maps assist in student learning in a constructivist classroom?

Students in this study were asked to design concept maps as an assessment measure and a final achievement tool. Students obtained nodes from the teacher researcher and the students provided label links based upon their understanding after a course of instruction in two topics, photosynthesis/respiration and genetics. The students concept maps represent the connections and relationships drawn from the lists provided. Students suggested during interviews that concept maps strongly assisted in clarifying connections and reviewing understandings between terms used in the Living Environment course. Sample student concept maps are seen in Figure 4.7 and Figure 4.8 for photosynthesis/ respiration and genetics, respectively and were scored for further quantitative analysis.

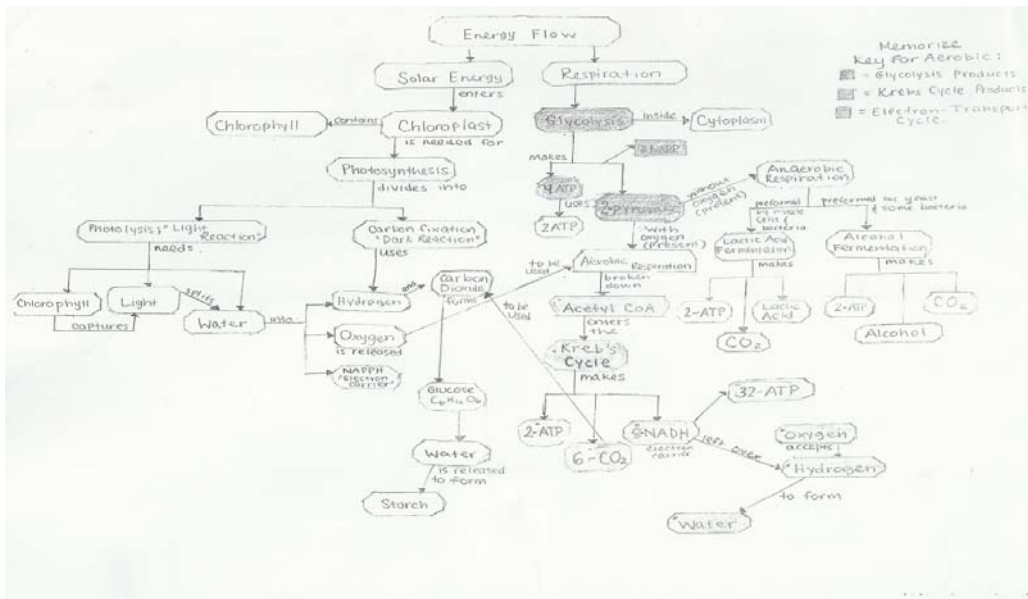


Figure 4.7: Sample concept Map of Photosynthesis/Respiration terms graded during achievement measure.

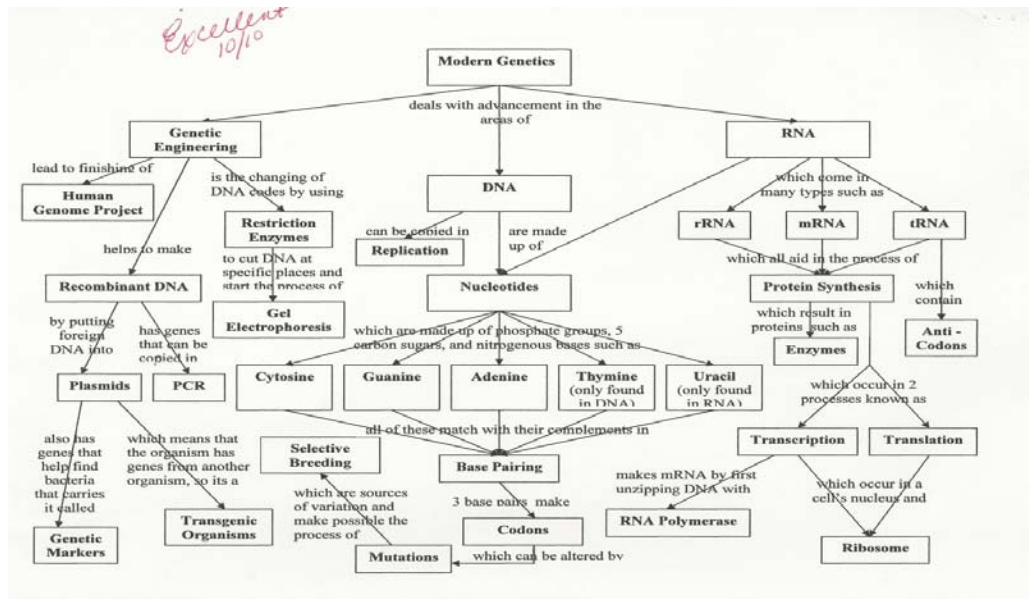


Figure 4.8: Sample concept map of Genetics terms graded during achievement measure.

Use of concept maps in school instruction will increase substantially over the next two decades. Concept maps cannot be used on national achievement tests until most students have been given the opportunity to learn and use this tool (Novak & Canas, 2006).

The third analysis in this study continues with qualitative analysis of data based upon the outlined research questions, introduced in Chapter 1. The qualitative data included several retrospective interviews during Year 1 & Year 2; the interviews resembled a verbal questionnaire with prodding questions. Twenty-eight students (16 males and 12 females) were interviewed individually (see one complete interview in Appendix XI) or in groups of two. The interviews were held on school grounds between June 6 – June 10, post instruction in photosynthesis/respiration and genetics but prior to the Living Environment Regents examination and the close of each respective school year. Questions and students’ responses were aimed to address the research questions in this study, as applicable, while providing insight on constructivist teaching methodologies.

3b. How do students socially construct understandings in light of positivist, quantitative research in the constructivist classroom and post testing?

Students were probed during student interviews if responses were unclear or simplified to the extent that the question remained unanswered. If the students made statements which directly assessed the learning of photosynthesis/respiration and genetics but were not a result of structured questions, again students were probed for deeper meaning/understanding. The interview framework was flexible and students periodically discussed different questions or ideas that related to their overall experience in the constructivist classroom. The teacher researcher explained to the students that they should feel free to respond at will, freely and openly, such that none of these responses would be used for grading and it was understood anonymity would be used with regards to identifiable student responses.

In this section, for each of the 10 interview questions, selected student responses and a summary of those responses were presented. Aspects of the interviews were used to correlate the quantitative data collected for research questions 2c & 2d and 3c & 3d, respectively.

1. *How helpful were the use of concept maps in your understanding of P/R/G?*

Most students indicated that concept maps were very difficult to construct and the time it took made the task very frustrating. Out of 28 students, 19 stated concept maps aided in clarifying ideas between the concept nodes given to review. A few student responses included:

“Photosynthesis and respiration was the hardest topic, helped to clarify things”.

“I didn’t like concept maps, but it did help”

“I didn’t like making the maps because I’m a perfectionist and it took me a really long time to finish”.

“Helpful to understand the flow, using more than one body system would be helpful if done in a concept map, together”

“Very useful, I actually used the text book and my notes when I usually never use them to make sense of the topic”

“Concept Maps confused me more, very confusing to plug everything in, wasn’t sure how to connect terms but didn’t really like putting them in the boxes. I get how they are connected”

“It should be done before the test.”

2. *Which tools (activities) used by the teacher, if any, helped you to understand the ideas tested in P/R/G?*

Most students chose a variety of tools which they believed helped in understanding the concepts P/R/G. Overall the students thought the most useful items were visuals (videos and pictures) used to enhance understanding. Students also believed that the hands-on items, especially preliminary concept maps and laboratory activities (tasks which enabled students to follow a hypothesis through to data outcomes), were most useful, while laboratory and homework were deemed as least useful with the exception of the importance of homework for review of vocabulary (Table 4.19). A few student responses included:

“Movie clips and labs”

“Need interesting labs”

“Homework and PowerPoint”

“Like to read the textbook but mapping the pathways was important to connect how and why things were happening”

“Video’s and pictures makes things more visual, more clear when I can see a picture”

“Video clips were best to help in learning”

“Labs helped most, easier when learning was hands on”

“Video clips were good, homework- way too much, concept maps-no way”

3. *Did you enjoy learning about P/R/G? What did you enjoy?*

Overall, students enjoyed learning genetics over photosynthesis/respiration. Students suggested that photosynthesis/respiration involved too much memorization and they had difficulty with the chemical equations and molecular pathway relevance. Even though several pathways are noted in genetics, the students identified with the ability to understand how we inherit characteristics, disease and genetically modify organisms for disease treatments. Out of 28 students, 23 preferred learning genetics over photosynthesis/respiration. In order to further clarify instruction and the availability of resources, many more video clips and laboratory activities took place during the instruction of genetics over photosynthesis/respiration. A few student responses included:

“Genetics, understanding where traits come from but P/R you can’t see it happening, not tangible.”

“DNA and how it works with the organelles.”

“I didn’t enjoy P/R/G but I’m glad I learned it”.

“I like genetics technology, switching genes and it makes me think of evolution and ecology, draws connections to other units”

“No, I like ecology better and the circulatory system. I don’t want to learn about plants, I want to learn about the human body”

4. *Do you now understand more about P/R/G as compared to your previous experiences regarding P/R/G?*

The students in this study, as advanced track students, were exposed to life science units such as P/R/G in 7th grade, therefore already having previous knowledge about the topics presented. The students stated the middle school teachers provided a general overview of the topics but they did not understand photosynthesis/respiration and genetics until this course because this course detailed the processes in greater depth than in previous courses. Students suggested that the increase in detailed allowed for enhanced understanding. The 28 students agreed that the learning and knowledge gained in photosynthesis/respiration/genetics was enhanced when compared to previous experiences. A few student responses included:

“I understand it more now, because it went more in depth, surface learning doesn’t work”

“Didn’t remember anything from 7th grade, learned everything this year with you [teacher researcher]”

“Punnett square carried over, easier seeing it the second time but not P/R.”

“In 7th grade it was just memorized but during 9th grade you have to think and know what stuff actually means. You need to know, what you believe is happening.”

5. *Is P/R/G difficult to learn? Why?*

P/R/G in several studies has been identified as difficult to learn but this interview question goaled to identify what mostly caused the learning difficulty. Overall, students agreed it was the connections between pathways and chemical processes that were complicated making it more difficult to learn, remember and follow P/R/G if you did not take the time to understand. All 28 students interviewed agreed that the learning photosynthesis/respiration/genetics was difficult but improved when learning was more student centered and visual. A few student responses included:

- “You have to love the topic, if you don’t then harder to learn.”
- “Hard to understand and know, concept maps, hard to do”
- “Too technical and plants are boring – so many terms”
- “Once you get lost, it is difficult to catch up and understand everything”
- “I understand things better when it is hands on”
- “Steps were difficult, to keep track of”

6. *Were Internet movie clips, interactive Internet web sites (i.e. Dolan Learning Center activities), concept maps, homework assignments, laboratory activities, etc. useful in your understanding of P/R/G? What helped the most, rank them if you think you can?*

Most of the students provided specific examples of images or video clips which helped them to understand a specific P/R/G concept taught. Out of 28 students, 10 students ranked the learning tools. Items with the highest ranking’s included video’s, websites, concept maps, laboratory activities (inquiry-based activities) and homework; the listed tools all ranked above 7 except for one student ranking of videos, on a scale of 10 to 1 (10 being most useful, 1 providing little to no assistance in learning) as important tools when learning photosynthesis/respiration/genetics (see Table 4.19).

Table 4.19: Number of students per ranking delineation for use of P/R/G instructional tools. (N=10)
Each number represents the number of students who provided the rank for the particular instructional tool.

Rank	Video Clips/Images	Concept Maps	Interactive Websites	Homework	Laboratory
10	4	3	2	2	1
9	5	4	3		5
8		1	5	3	2
7		2		5	3
6					
5					
4	1				
3					
2					
1					

A few student responses included:

“Homework and video’s cleared things up”

“Pictures helped making sense between P/R. Not really in genetics, in genetics we had to know the terms first then the video’s really helped.”

“Probably helped more by doing labs (you did it) and the visuals, making it easy to see”

“Video clips and interactive sites helped me to learn stuff, like the one where we had to cut the DNA and the Tony lab.”

7. *Please answer the following questions regarding P/R/G:*

a. *What is a sex-linked disorder?*

b. *How can we identify it?*

c. *Using a pedigree regarding sex-linked diseases, what could we learn? Could it be fixed using genetic engineering?*

d. *Do plants complete respiration, photosynthesis, or both?*

e. *Why did you choose your answer?*

Throughout the interviews, student respondents referred to specific concepts taught about P/R/G. The interviews were held approximately 3 months post instruction of these concepts in the classroom. Out of 28 students interviewed, 23 remembered precisely about sex-linked disorders, while several discussed pedigrees without yet being asked interview question 7c. Most of the students stated plants must complete both respiration and photosynthesis immediately; out of 28 students’ 26 students understood why both reactions are necessary to sustain life in plants, two with prodding were able to reach the correct conclusion. A few student responses included:

“A pedigree will help in diagnosing colorblindness”

“It tells us whether or not we should have children”

“Disease carried on sex chromosome; X or Y [Didn’t remember how to identify]”.
You can only fix the disease if you fix the zygote, not later – too difficult”

“Pedigree can trace a sex linked disease easily.”

“ALD – found on the mom’s chromosome”

“Plants don’t do respiration” [but after prodding] the student stated they need to make energy, ATP therefore they must do respiration”.

“Photosynthesis makes their food and respiration turns it into energy”

“Ms. XXXXXX (teacher researcher) said they did both” – [5x’s students stated this response]

9. *Did you think the information learned regarding P/R/G is useful to you?
How does it help you? (Outside of school)*

Generally, student responses stated that unless you were a medical professional or scientist you did not need to know about P/R, but genetics might be useful if you have a disease or want to have children. A few student responses included:

“Really good to know, can always use information about something you don’t know”
“Only if you want to be a scientist, but in that movie [Lorenzo’s Oil, 1992], they helped cure their son by learning all of that science.”
“I guess if you have a sick child and we know not to cut down the rainforest”

10. *Did the two-tier diagnostic (reasoning) exam and the multiple choice (standardized) exams accurately assess what you know about P/R/G?*

Overwhelmingly students responded that the diagnostic (reasoning) examinations better assessed their understanding because they could not guess; they were forced to know the topic and rationale behind their answers. In MC tests, students stated they could guess between two answers they believed were correct and had a 50% chance to get the question correct. Out of 28 students, 23 agreed two-tier diagnostic (reasoning) examinations better assessed their understanding of P/R/G, three stated MC was better to assess their knowledge and two agreed both examinations equally tested their knowledge of P/R/G. A few student responses included:

“MC you can guess a random answer and be right but reasoning, you have to know the answer. On a difficult topic I would rather do diagnostic but an easy topic where I don’t have to think as much, I would rather do MC”
“I hated the diagnostic, it helped but got confusing, and the matching was hard”. “It was difficult”.
“MC you can guess and be lucky, but diagnostic you will probably get caught”

11. *Did anyone task you completed this year help in your understanding of P/R/G? Explain your answer.*

Students referred to previous teaching instruments and learning environment as important in enhancing their knowledge of P/R/G. A few student responses included:

“Genetics video clips with translocation was very good, made things clearer.”

“School could give more money to show how these things really happen... more experiments”

“I like that we all seem to be having a good time in class, we all laugh together about what we are learning”

“Anything visual and I like to talk”

“Write your own notes, you always say that, I like that I have to think for myself and not just copy notes”

“You telling us not to copy all of your notes but to put them in your own words”

3c. Which learning instrument do students perceive best assists in their understanding of photosynthesis/ respiration and genetics?

Information as provided from verbal student responses was quantified to answer research question 3c and 3d. Ninety percent ($n=10$) students interviewed stated that videos and visual representations and eighty percent ($n=10$) of the students stated concept maps reviewing concepts taught, best assessed the knowledge gained during their course of study of the two topics (P/R/G) presented. They explained that the visual representations clarified pathway and reactions in P/R/G that otherwise were not tangible. The students also inferred that websites, laboratory activities (inquiry-based activities), and homework were also very important tools in the learning process because when they applied their knowledge to a task it was easier to decipher what they didn't know. They were also encouraged by the amount of information they did understand when completing the concept maps and on the achievement measures that followed the course of instruction.

3d. Which measure do students perceive best measures their level of understanding of photosynthesis/ respiration and genetics?

Eighty two percent of students interviewed stated that diagnostic testing best assessed the knowledge gained during their course of study of the two topics (P/R/G) presented. The students explained that little room was left for random guessing when they were unsure of an answer because the reasoning answer must match the initial multiple-choice answer. They were also encouraged by the amount of information they did understand and how they could relate facts with the significance of taught information. Several students referred to MC questions as easy because if they were unsure of a particular answer, random guessing provided them a greater chance of

accurate scoring, especially if they could eliminate one or two of the distractors. Eleven percent of the students stated MC standardized examinations were the best measure of their knowledge and seven percent of the student interviews were indecisive about which achievement examination best measured their knowledge of the topics photosynthesis/respiration and genetics.

Triangulation includes the collection and review of data through several means in order to achieve a more accurate and valid understanding of a study construct. In this study, several techniques were used to assess student learning and instruction in an advanced Living Environment course. Dual triangulation included the combining of two triangulation analyses to compare six methodologies to answer this study's research questions. Research questions 3e and 3f represent each type of data analyses involved in one triangulation group.

3e. What is the correlation between students' attitudes towards science, post instruction and their understanding of photosynthesis/respiration and genetics via interviews and assessment responses concept maps interviews in an advanced secondary science living environment course?

In monitoring students' attitudes towards science, interviews and concept map pre-achievement assessments data analysis that student attitudes (particularly in Year 2) are positive with regards to instruction in a constructivist, advanced, Living Environment class room. Interviews matched TOSRA and concept maps assessments with regards to student increased enjoyment of learning experiences and adoption of scientific attitudes primarily in males. Interviews also supported the use of concept maps as learning tools while incorporation in visuals, interactive websites, and inquiry based activities increased students enjoyment of P/R/G and after review of consistencies or variations between male and female pretest and posttest responses. It can be noted that males increased their attitude toward the social benefits of science (Year 1), Adoption of Scientific Attitudes (Year 1 & Year 2) & Enjoyment of Science Lessons (Year 2). These gender based outcomes mirrored the interviews as the male students referred to the importance of science study in high school and beyond, and what is learned will assist the (male) students in making more informed decisions as adults. All students also discussed the necessity of

increasing laboratory activities for student learning. In addition, females attitudes towards social problems and benefits were more positive (Year 1) and directly correlates the TOSRA consistencies with student interviews. Female students stated they needed to know and understand P/R/G along with other topics in biology in order to make informed decisions in life. Triangulation was achieved for student attitudes towards all TOSRA scales with the exception of Normality of Scientists, student interview outcomes and usefulness of concept maps in learning P/R/G. All quantitative outcomes were supported by qualitative statements made during student interviews.

3f. What is the correlation between student performance on past-standardized multiple choice examinations, the two-tier diagnostic examinations, concept maps and the Living Environment Regents examination and their understanding of photosynthesis/respiration and genetics in an advanced secondary science living environment course?

Triangulation was not achieved in the case of student performance on all achievement measures. Past-standardized multiple choice examinations showed 73.5% overall score, the two-tier diagnostic examinations 62% overall score, and the Living Environment Regents examination 87% overall score in photosynthesis/respiration in this study's advanced Living Environment course (Year 1 & 2). Past-standardized multiple choice examinations showed 85.5% overall score, the two-tier diagnostic examinations 66.5% overall score, concept maps 70% overall score and the Living Environment Regents examination 81% overall score in genetics in this study's advanced Living Environment course (Year 1 & 2). No correlation was seen between the past-standardized multiple choice examinations and the two tier multiple choice tests when compared against the Living Environment Regents examination (Years 1 & 2). This supports the original thesis idea that the LER and two-tier multiple choice diagnostic tests do not correlate in advanced Living Environment students.

3g. What is the correlation between student performance on past-standardized multiple choice examinations, the two-tier diagnostic examinations, concept maps and the Living Environment Regents examination in

photosynthesis/respiration and genetics, when compared to student responses on the *Test of Science Related Attitudes* pre- and post-tests and student interviews in an advanced secondary science living environment course?

In correlating student performance on past-standardized multiple choice examinations, the two-tier diagnostic examinations, concept maps and the Living Environment Regents examination in photosynthesis/respiration and genetics, when compared to student responses on the *Test of Science Related Attitudes* pre- and post-tests and student interviews in an advanced secondary science living environment course it can be implied that student exhibited positive attitudes towards science (outlined with TOSRA correlations), interviews suggest students enjoy and understand the topics of P/R/G and suggested that creation of concept maps, even though tedious, benefited student learning. Finally student scores on the past-standardized examinations matched with the first triangulation method.

4.5 Chapter Summary

This chapter's findings have addressed all of the research questions presented in this study. The methodology of the study addressed both qualitative and quantitative approaches to evaluate the study rationale of the inability of the NYS LER to properly assess learning in advanced, Living Environment students. The research questions can be collaboratively discussed with regards to data outcomes as follows:

Research Question#1: How do student attitudes correlate with scoring on standardized multiple choice examinations, two-tier diagnostic examinations, concept maps, and the NYS Living Environment Regents in photosynthesis/respiration and genetics?

The substantial and underlining research questions in this group reviewed descriptive statistics for quantitative analysis for the reliability of TOSRA and achievement measures to address the study's first group of research questions. Students' attitudes toward science were established post 10 months of constructivist teaching and showed increases in Year 2 with regards to Enjoyment of Science Lessons and Career Interests in Science (Table 4.2). Students should be exposed to scientists to

encourage personal motivation in science and career options in science. Group work (digital, inquiry labs, and video's), connections with scientist in the field (physical or virtual), and adaptability in the learning environment may encourage personal motivation and increased interest among learners and drive aspirations of students to learn (Huang et al., 2010; Table 4.3). The analysis of TOSRA showed statistically significant differences between pre and posttests in males and females (Table 4.4 – 4.6; see Figures 4.3-4.6).

The research questions in this group focused on inferential statistics with quantitative data using reliabilities and correlations coupled with qualitative data from student interviews to address assessments and achievement measures. Assessments of achievement measure average means as a method to measure understanding were reviewed. Increased achievement scores were noted in the Living Environment Regents examination but not in the two-tier diagnostic examinations, past-standardized multiple choice examinations, and concept maps in photosynthesis/respiration and genetics for most students. There were also significant differences in achievement measures to assess learning. Diagnostic tests may fully evoke recall of conceptual understanding and therefore pose more difficulty in ascertaining mastery in achievement measures whereas the Living Environment regents superficial questioning may allow for simple reasoning to determine test item outcomes with a higher degree of accuracy. Overall academic achievement on the Living Environment regents may be attributed to constructivist teaching (Kim, 2005).

Research Question#2: How does advanced student understanding of photosynthesis/respiration and genetics correlate with gender of students and scoring on standardized multiple choice examinations, two-tier diagnostic examinations, concept maps, and the NYS Living Environment Regents?

Understanding in a constructivist classroom is the major construct of this teaching style. Cooperative groups, inquiry based learning, and deconstruction of misconceptions should result in enhanced understanding of topics presented. Initially the concept maps were used to encourage constructivist teaching interventions and enhance understanding and achievement but when used as an

achievement measure, lack of understanding, misunderstanding, alternative conceptions, and misconceptions were identified in several students' work. Mastery of genetics and reasoning associated with conceptual learning can be daunting (Hickey et al., 2003). The difficulty in achieving understanding due to limitations in student reasoning may be contributing factors for the lower achievement scores on concept maps and diagnostic examinations while the lack of correlation between the Living Environment Regents examinations and standardized examinations may support reduced reasoning was needed for mastery achievement on those examinations (see Tables 4.9 - 4.12). Additionally, the same trend was noted when comparing first tier to second tier responses on diagnostic examinations (see Tables 4.15 - 4.18); the first tier supports less reasoning therefore most students achievement was higher than on the responses from the second tier questions which required advanced reasoning skills. Reasoning and correlations are needed to truly understand genetics concepts (Hickey et al., 2003). In addition, during the interview process many students determined the concept maps were useful but difficult as a learning tool because the vocabulary in biology is so vast universal learning was still prohibitive for many (Kim, 2005). This study may conclude that constructivist teaching is effective in terms of understanding as noted in student interviews but not in terms of photosynthesis/respiration and genetics achievement but had some effect on student motivation to learn, to self-monitor their learning, and that students enjoyed a constructivist teaching classroom environment (Huang et al., 2010).

Research Question#3: How does assessment type, student understanding, and student attitudes correlate with achievement scores on standardized multiple choice examinations, two-tier diagnostic examinations, concept maps, and the NYS Living Environment Regents after a course of constructivist teachings?

Overall, the final groups of research questions were addressed using triangulation methods to investigate how understanding coupled with student attitude and assessment types all played collaboratively played a role in student achievement in a gifted Living Environment classroom. The first triangulation method was consistent with all methodology findings. Students enjoyed learning science, as presented in TOSRA even though pre-assessment of concept maps proved difficult they also

perceived this tool as useful in the learning process. The second triangulation method showed inconsistent results, the past-standardized multiple choice examinations, concept maps and the Living Environment Regents examination in photosynthesis/respiration and genetics did not compare with the students' performance in the two-tier diagnostic examinations.

Overall, triangulation methods showed achievement measures used by NYS do not adequately correlate with student understanding and learning. The diagnostic examinations as achievement measures in a constructivist, advanced, Living Environment class room do not match student qualitative responses regarding their usefulness in learning (approximately 63% average on all exams). The diagnostic test scores were lower than all other achievement measures even though students stated the diagnostic exams were a better measure of their understanding and encouraged higher order-thinking and better study habits in preparation for examination.

Chapter 5

SUMMARY, CONCLUSIONS, LIMITATIONS, AND IMPLICATIONS

5.1 Overview of Chapter

The purpose of this study was to evaluate correlations between student understandings, attitudes alongside achievement when measured by two-tiered multiple choice diagnostic tests, past-standardized test questions with advanced placement test items, concept maps and the New York State (NYS) Living Environment Regents examination (specifically questions on genetics and photosynthesis/respiration) as a means to best measure understanding, attitude and achievement of core science curricula in NYS Living Environment courses for advanced/gifted secondary male and female students over two years. In addition, this study proposed to identify which measures of achievement (past standardized multiple choice exams, concept maps, two-tier multiple choice diagnostic exams and the NYS Living Environment Regents) best assess students' understanding and learning as it correlates to student attitudes using interviews and the *Test of Science Related Attitudes* (TOSRA) for males and females over two years.

This chapter concludes the thesis by addressing five important areas divided into five sections. The chapter overview is presented (Section 5.1) and the following sections present a summary of results/findings (Section 5.2), limitations, implications, and significance of the study (Section 5.3), recommendations for future investigations (Section 5.4) and closes with the summary of chapter (Section 5.5).

5.2 Summary of Results/Major Findings for Chapter 4

In recent years, the focus on STEM (Science, Technology, Engineering, and Math) has been on the forefront of science educators', administrators', and policy makers' minds. With good reason, increased skills and encouragement of future generations to focus on scientific and technological advancements will provide tools for the next

generation to excel in the workforce and identify techniques for the betterment of science and society (Glass, 2013). Students need to understand science and express knowledge obtained as a means to complete these tasks. In this study, advanced students in the NYS Living Environment courses were instructed and data were obtained on the correlation between constructivist teaching practices and achievement measures as a means to evaluate three achievement examinations to evaluate learning and to compare these outcomes to students' attitudes and perceptions.

The main outcomes of this research associated with the study's research questions were encompassed under the broad headings of descriptive and inferential statistics for all examinations under investigation, correlations between the tested variables, and dual triangulation of quantitative and qualitative data. A summary of the findings is as follows:

1. Males showed significant improvements in positive attitudes towards science using the TOSRA pretest to posttest. Females also showed improved positive attitudes towards science using the TOSRA but exhibited this change to a lesser amount than that of their male counterparts. Social Implications of Science showed the most significant improvement in both genders after instruction in a constructivist Living Environment classroom. Student attitudes towards science increased slightly towards the positive after ten months of constructivist teaching in Year 2 for all TOSRA scales except Attitudes towards Scientific Inquiry.
2. The NYS Living Environment Regents does not adequately assess understanding of the topics of photosynthesis/respiration and genetics for advanced students when compared against student interviews, standardized tests, concept maps and two-tier diagnostic examinations. A cumulative review of all students' diagnostic examination outcomes showed the first tier multiple choice questions exhibited a 10% (Year 1) and 19% (Year 2) increased in accuracy during assessments over the second tier reasoning questions for both photosynthesis/respiration and genetics, respectively. Standardized examinations best assessed student learning via reliability of achievement measures but two tier diagnostic examinations also showed

promise as good assessment measures when coupled with student interviews. Overall, advanced students understanding was best measured using advanced/college level standardized test questions after a course of constructivist teaching of photosynthesis/respiration and genetics which included both terminology drills and discovery learning with content review. Females showed greater achievement on all photosynthesis/respiration examinations (past standardized multiple choice exams, concept maps, two-tier multiple choice diagnostic exams, and the NYS Living Environment Regents) and achievement measures over males but the converse was exhibited for the genetics unit.

3. Qualitative and quantitative data triangulation outlined during student interviews showed decreased student enjoyment of completing concept maps tasks but reinforced the importance of concept map use in review of difficult topics such as genetics and photosynthesis/respiration. In addition, students also perceived that the diagnostic examinations were more difficult than the typical items identified on the NYS Living Environment and standardized tests from previously released sources but constructivist interventions (video clips, technology, debates, and concept maps) not only made learning easier but assisted in content recall and achievement on all assessment measures.

5.2.1 Constructivist teaching

Constructivist teaching styles versus traditional teaching methodologies have been on the forefront of education experts' agendas in order to determine the techniques needed to help students understand various concepts in science for sound learning and at a deeper level (see for example, Chiappetta & Koballa, 2006; Duit & Confrey 1996; White, 1998). Issues identified in the literature include teachers not being sensitive to students' existing conceptions, ideas and prejudices; interpreting students' answers/responses in a way that is contrary to the actual students' own idea; and teaching that does not challenge higher cognitive levels of learning (Driver & Scott, 1996; Duit & Confrey, 1996; Duit & Treagust, 2003; Wiggins & McTighe, 2008).

There are trends where constructivist teaching is in line with both Piaget's and Vygotsky's works where students can have their cognition development enhanced through cooperative discovery work amongst peers. Specific content may only be understood and mastered after scientific topics are introduced by the science teacher. An integration approach should be adopted by science teachers (Bächtold, 2013).

The best means to support learning is by providing resources for retrieving knowledge through reconstruction of taught content. Discovery learning may instead inhibit understanding because the core content is unfamiliar to the student learner thereby a possible revalidation of learning styles for progressive educators should occur (Belluck, 2011). This approach should not negate the teacher/student use of visual learning tools, UbD techniques, concept maps, interactive debates, and review of content using multiple exploratory techniques to solidify understanding and to provide improved methods for retrieval of facts. Detailed diagramming of the material taught forces students to make connections among facts but cannot be used as the sole means of promoting understanding; it is necessary to also encourage students to memorize facts that will be asked during a recall of content examination (Belluck, 2011).

5.2.2 Standardized test questions

Standardized testing, while sometimes perceived as factually dense, but demonstrated students' coherent ability to assess content learned and application of content taught mirroring previous findings (Belluck, 2011) for advanced NYS Living Environment students in the topics of photosynthesis/respiration and genetics. The accurate answering of standardized questions was a result of multiple practices which occurred in the constructivist classroom. The questions accurately assessed achievement ascertained by the students after a course of instruction.

An issue associated with standardized examinations is that students have learned to become excellent memorizers thereby dampening their desire to question content taught. Student perception of examination types/tasks may encourage their use or disuse of different levels of intellectual skills and abilities as outlined in Bloom's taxonomy of educational objectives. Students have reported associations between

test and assignment demands and preparation strategies; relationships have been previously identified where perception of higher levels of cognitive processes (reasoning, analysis, etc.) vs. lower levels of cognition processes (rote memorization/factual recall) in preparation for examinations and employment of learning strategies may not show direct correlation (see Scouller, 1998). If adoptions of deep preparation strategies are used in the classroom (found in combined social and cognitive constructivist teaching practices), multiple choice test achievement scores should be consistent with student learning thereby systematically removing limiting factors which may affect learning approaches and achievement examination outcomes associated with the assessment of learning.

This study's research findings include those where students scored much higher on standardized items when compared to the same concepts on the first tier diagnostic test but when asked critical thinking items (second tier reasoning items) students inaccurately answered items on the diagnostic examination. High standardized test scores may assess student understanding of photosynthesis/respiration and genetics, even though students' favored the diagnostic examinations because they believed these examinations "forced them to study more" as revealed in student interviews. Diagnostic examinations may be favored by students because they understood content well enough to draw accurate conclusions using recall on both tiers of the multiple choice questions.

Overall, Belluck (2011) showed that relationships between learning (enhanced cognition) and achievement (high scoring) on examinations are student and teacher dependent. In addition, a statement by Harvard College professor, Howard Gardner, concluded that constructivist approaches which primarily focus on learning that emphasize student inquiry over memorization may inhibit student learning and achievement on examinations (Belluck, 2011).

5.2.3 Two-tier diagnostic examinations

Students who achieved well on the standardized test, but achieved lower scores on the second tier diagnostic test still acknowledged the diagnostic test as a better measure of their understanding during interview. Diagnostic testing proposes a better

method for measuring student understanding and learning because students and teachers will be made more aware of student's alternate conceptions instead assuming knowledge based upon MC scoring outcomes. Diagnostic tests help student understanding of concepts and hypotheses while encouraging teachers to re-evaluate teaching practices. Diagnostic examinations may be most useful as tools for review. Teachers may realize while teaching and reviewing diagnostic assessments that they taught alternative concepts to students and that they may lack understanding about specific portions of science content. Holistically, the diagnostic examination provides teachers and students with an opportunity to diagnose learning without interviews while collectively increasing the quality of teaching and student learning without solely relying on rote memorization of facts but via gaining knowledge of concepts.

5.2.4 New York State Living Environment Regents Examination

The goals of the New York State Living Environment Regents' are to assess achievement of all NYS life science students' knowledge taking the associated course; particularly in this study, two topics in the curriculum were under investigation for advanced LER students. In addition, this study's data support the argument that the tests created and interpreted as valid representations of NYS Living Environment student test taker knowledge are inadequate. Finally, this study concludes that the New York State Board of Regents did not raise the "educational testing bar" when they moved from RCT's to Regents examinations in science. The Living Environment Regents examination was designed to evaluate a vast body of students with multiple intelligences but does not adequately review the knowledge and skills of advanced/gifted students and therefore a new examination or exception examinations should be created to support and assess advanced student understanding.

5.3 Limitations, Implications, and Significance of the Study

There are several limitations in this study which should be considered before definitive conclusions can be drawn. A number of constraints served as limitations for this study in spite of several tasks to diminish the effects of these limitations. The population used in this study was from one high school in New York which exhibited

limited diversity in racial, social, and economic status with a small sample size when compared against the vast number of students who participate in NYS Living Environment testing. In addition, the Living Environment Regents examination items were limited to the number of items presented on the 2006 and 2007 LER and limits an adequate correlations to the number of items used in the classroom for both the diagnostic and more particularly the standardized examinations. Overall, despite the wealth of data collected, more study is needed to draw a positive correlation with scores on standardized examinations and constructivist teaching approaches and the outcomes of the two tier diagnostic examinations, TOSRA pretest and posttests, to determine the inadequacy of the entire NYS Living Environment examination to assess understanding in advanced students. This study if compared to data collected in other studies may encourage dialogue regarding the inequity of testing standards which truly measure achievement for the advanced student populations in NYS. Possibly a full LER examination when compared against other test items (standardized and two- tier multiple choice examinations) may show that various item presentations will not affect the validity of test-score interpretations. Nonetheless, the study does bring to the foreground a strong need to reexamine the cumulative examination items employed for advanced LE students in NYS.

5.3.1 Limitations

Limitations exist in all research studies. During the investigation of variables associated with exploring teaching and learning and achievement measures of advanced students in NYS Living Environment classrooms the following limitations were outlined below. Specific limitations in this study include:

1. The school used in this study was used for several reasons: it showed similar demographics for socio/economic status for NYS “advanced” populations but lacked an abundance of racial and cultural diversity therefore possibly creating a limitation in this study. A broader group of schools, instead of one NYS school should be reviewed in an extension to this study to include advanced students of diverse backgrounds. In review, a school with higher than average achievement instead of a school presenting poorer high stakes test outcomes was used because low stakes populations possibly presents

other factors which may diminish achievement thereby making the interpretation of qualitative data more difficult. Not only may the NYS Living Environment not assess understanding in advanced students but it may also not assess understanding in all Living Environment students, this premise requires further investigation. In addition, cultural backgrounds may influence student perception and perceptions of student-teacher interactions and should be reviewed for the constructivist classroom.

2. Year 1 data posttests were collected after the teaching portion of the school year ended. Students were completing post TOSRA after completing a cumulative three hour standardized Living Environment Regents examination covering all topics learned annually and may have inadequately or inadvertently rushed the answering of many posttest items. The data of Year 1 items may have skewed the actually correlative results of the TOSRA and should be reviewed for reliability and validity.
3. Teachers, due to the pressures associated with high stakes testing, even those who employ constructivist teaching practices, may shift the teaching focus from how understanding of science is primarily for the benefit of science and society to test preparation. A good example in this study may have been identified with the minimalistic outcomes on the TOSRA with regards to how constructivist informed teaching influenced students' leisure science attitude change as denoted in Year 1 pretest to posttest TOSRA scale.
4. Concept map assessment using a simplified scoring procedure may not be feasible due to the following limitations in concept map design and review: 1) intricacies of grading nodes and interpretation of linking terms may not be clearly defined in a concept map rubric; 2) understanding by students of the approach in organizing concept terms, cultural influences, technological influences, and study practices while creating their concept map may limit the teachers ability to adequately assess meaning; 3) time to complete assessments accurately and teacher understanding of the teaching unit to adequately assess student derived interconnections is a limiting factor; and 4) a huge delineation of time is needed to appropriately address connective-ness of student thoughts as a means to assess what the students meant in all aspects of the map design. A possible solution may be to rescore concept maps using students in cooperative learning groups proctored by the teacher

and to provide an established concept map rubric after students have observed and practiced the techniques to achieve mastery in this style of review (for further review, see Novak & Gowin, 1984).

5. Previously the students used in this study may have worked with constructivist-informed teachers in other courses therefore the teaching style was not novel and students may have already perceived this technique as not as useful as rote memorization techniques. This student perception may have contributed to the minimal changes in students' attitudes towards inquiry.
6. Cultural backgrounds should be examined as a factor for success in culturally diverse student population from that of the teacher in the advanced Living Environment classrooms used in this study. Deconstruction of preconceived knowledge plays an important role in reconstruction of curriculum content understanding. Therefore if teachers are unaware of cultural tradition they will not initiate conversation to alter student misconceptions in a given area of investigation.
7. Word choice use may increase difficulty with diagnostic or standardized multiple choice examinations measure of achievement because the word choices used in questioning may inhibit students' ability to accurately review cognition or measure knowledge for items in question. With regards to diagnostic examinations second tier questions multiple choice or free response statements, an unfortunate concomitant degree of error may exist in the description of students' conceptual framework with forced choice second tier responses (Griffard & Wandersee, 2001). Despite the consequences, students believe two-tier multiple choice diagnostic examinations help in revealing alternative concepts as expressed in this study's student interviews.
8. Previous works express the difficulty of making valid inferences associated with student performance based upon examination scores. Limitations in standard psychometric procedures thereby inhibit the ability of test makers to develop all content encompassing test items. In addition, the understanding of a large student population is usually inaccurately measured by the teacher and statewide test producers while accurate guessing of information on examination provides a uncorrectable variable for validation of student achievement (Reich, 2013; Tamir, 1990; Yarroch, 1991).

9. Cultural factors within the population of secondary science students tested in New York State are not accounted for during the design of test items. Cultural differences between test constructors and test takers in American high schools can encourage incorrect answering of test items due to language, dialect, and cultural factors. Misinterpretation of meaning by students not considered by the writers of test items and item responses may play a major role in inaccurate responses on examination. A variety of factors play a role in retrieval and coherent inferences required for answering multiple choice test items such as the role of reasoning over that of recall when answering a test item (Reich, 2013).
10. A final limitation includes the breadth of information to teach with regards to P/R & G within a very discrete timeframe making it difficult to assess misconceptions and re-teach for understanding before accurate measure of student achievement using annual, high stakes, cumulative testing. Over previous decades science teachers have devoted resources, effort, and vocation to implementing constructivist rationales via the method of science inquiry based lesson planning and teaching (Furtak, 2006). Constructivist practices which dictate science inquiry are time consuming, lack adequate correlation to performance indicators (“New York State Alternate Assessment Technical Report,” 2005) and sometimes require skills exceeding that of the student participant. Yet these tasks are necessary to improve how students learn and sub-sequentially increase the science ranking of the US as a nation. Possibly, more importantly, assessments of the wrong-answers resultant of student conceptions that may aid in diminishing the established framework of alternative conceptions students harbor (Tanner & Allen, 2005) currently not completed during high stakes testing.

5.3.2 Implications

Several implications from this study’s findings are important to note. A first implication is the use of advanced/college level multiple choice examination items coupled with post-test interviews items for assessment of advanced students knowledge for measure of the NYS Living Environment curriculum and Regents measure of achievement. Data from many studies have shown that examinations are

not as accurate as dialogue to measure the understanding of students as stated by multiple sources (Reich, 2013; Tamir, 1990; Yaroch, 1991). The New York Board of Regents should review testing procedures for all annual cumulative examinations given to students.

A second implication is the use of diagnostic instruments to review advanced student understanding more readily than practice LER items or standardized test items as echoed in students' interviews specifically when the multiple choice diagnostic test items mirror college level questioning. Diagnostic test items may serve as an excellent source of review and dictate if the teacher meets the goals of the LE curriculum guides with shortcomings in teaching/learning practices. Diagnostic instruments can assess students' knowledge in such a way that teachers are inhibited from teaching towards the test; this approach supports the premise and goals for the creation of the No Child Left Behind Act to encourage mastery of curriculum standards. In addition, empirical studies such as the one reported here can be used to determine whether or not students in classes of constructivist-informed teachers can achieve higher scores on diagnostic tools and have a deeper understanding of the concepts presented within the secondary science classroom.

A third implication is the use of various educational resources and techniques by educators to prepare students to be successful on standardized NYS LE tests. Teacher preparation for student learning should include the teaching of content facts and their memorization but also include inquiry-based exploration of learned text to promote reasoning, deconstruction of incorrect knowledge and the construction of appropriate knowledge in preparation for correlative assessment. Traditional teachers should adopt constructivist teacher principles which include aiding students in negotiating the significance between two or more factors when students are engaged in learning (Schrieber & Valle, 2013). Teachers and school districts may improperly interpret the outcomes of cumulative annual achievement examinations (i.e. the NYS LER) if scrutinized against the data in this study. Interpretation of the NYS LER as a benchmark of advanced student understanding may be incorrectly interpreted.

5.3.3 *Significance*

Constructivist-informed teaching is capable of enabling advanced students to develop deep and meaningful understanding of science topics and this level of understanding can be assessed by college level multiple choice standardized instruments. However, the Living Environment Regents examination does not measure student understanding at the deep and meaningful level and therefore do not differentiate between memorized knowledge and a deeper understanding of that knowledge specifically in advanced students. Conflicts arise between the benefits of statewide assessments and classroom assessments because external tests shape what goes on in the classroom in negative ways when the emphasis is shifted to drill and test preparation versus learning, inquiry and exploration. Consequently a median between the teaching styles is needed (Boston, 2002). In addition, past-standardized examinations did measure student understanding in the advanced classroom specifically when student questions were higher-order thinking (associated with the AP Biology test item bank).

A problem that arises is that students who achieve high scores on traditional standardized tests may not have a deep understanding of the topics and this will be detrimental to their studies at a higher academic level. The contention from this study is that the uses of multiple resources to measure understanding including practice multiple choices two tier items, exit interviews, and constructivist teaching practices associated with any given topic in the NYS Living Environment curriculum can better determine the level of understanding of advanced students. This is significant because state-wide assessments may need to be reevaluated to determine if students have actually achieved average skill or mastery of the Living Environment Curriculum topics as per the No Child Left Behind Act and the Elementary and Secondary Education Act (ESEA) designed under the current president, Barack Obama's tenure.

The NYS LER act of simplifying test items for an entire population to assess learning may inhibit proper assessment of advanced students' depth of knowledge. Gifted or advanced students more complete understanding may lead to them choosing an incorrect item answer because they believe the items presented as

correct may be too simplified. In essence, a simplified answer may lead to an incorrect item selection by the advanced student due to the belief that the simplest, yet correct answer is an insufficient answer to a given question (Reich, 2013). Yarroch (1991) and Tamir (1991) have attempted to address summative examination scores' inability to infer student understanding and their limited use to measure student knowledge (see Reich, 2013). Also, if the target student population establishes a lack of understanding, both teaching and testing styles should be modified to promote further understanding. Very little has changed to address these limitations of cumulative high stakes testing over the last two decades — the examinations used are both over-estimating and under-estimating student knowledge (Marmaroti & Galanopoulou, 2006).

Standardized tests, if modified to review and incorporate items triangulated during this present study, may better measure student understanding at a deep and meaningful level and thereby take steps to differentiate between memorized knowledge and a deeper understanding of that knowledge.

5.4 Recommendations for Future Investigations

Several recommendations should be reviewed further. An all-encompassing review of science topics associated with the NYS Living Environment Curriculum and Regents' examination for the assessment of advanced student learning could be investigated as a follow-up to this study. In addition, research should be conducted which includes following advanced student achievement in science courses while at the university; a clear measure of advanced secondary science student understanding may assist in programming science courses on the collegiate level. This investigation could be simplified to identify the number and type of science courses taken in the university and correlative course scores and formal tutorial services data during students' tenure throughout their university enrollment. This task may serve as an indicator of actual preliminary science learning on the secondary level.

In addition, continued modification and revision of the current NYS Living Environment Regents Examination should occur to provide an advanced vs. general population test component. Distinguishing learning ability is not discriminatory but

will serve to differentiate levels of understanding. This task could be accomplished using a newly derived Advanced Placement Diploma that differs from Diplomas of Distinction not based upon quantity of examinations completed but by advanced vs. general criteria's for examinations completed.

Finally, creation of diagnostic examinations for every Key Idea of the NYS Living Environment Core Curriculum as models for review of content and the use of examination of achievement trends in advanced students when taking higher level college courses or college courses at the university may serve as better indicators of student understanding. This may include the reduction of high stakes tests as components of students' annual scores. A correlation between learning and success outside of an annual high stakes examination will be a more coherent measure of advanced student understanding. As an aside, a reasoning format as seen in two tier multiple diagnostic examinations could be added as a possible supplementation to the current NYS LER testing module.

Overall, a larger consortium of students should be reviewed including a larger group of students from a wider variety of schools including both low and high stakes populations during a continuation of this study. In addition, teacher training on the effect of multicultural differences in the teaching/learning process should become the standard for teaching for differentiation. Constructivist practices should encourage the deconstruction of beliefs that may be foreign to the teacher if the teacher is aware of culture differences specifically when the student population greatly differs from the teachers' personal cultural group. The combination of identifying cultural differences between the student learner and teacher and identifying cultural differences associated with topics taught in the LE classroom may aid the teacher in recognizing misconceptions necessitating deconstruction.

5.5 Summary of Chapter

This study goaled to ascertain understanding about testing practices currently used to measure understanding for advanced LE high school students. Many outcomes in this study should encourage change in the current assessment procedures used for NYS advanced LER students annual, cumulative high stakes examination. The most

statistically significant findings were the correlation of advanced/college level questioning as a better measure of advanced student understanding that greatly differed from the items identified on the NYS LER. In addition, identifying the correlation between testing achievement for females in understanding photosynthesis/respiration over that of their male counterparts and the converse for genetics was unusual and deems additional investigation of why specific topic understandings may favor males over females and the reverse as outlined in this work.

Secondly, as a result of how high stakes testing is used to dictate teaching and learning, educators have no choice but to continue to monitor their students' progress with achievement measures which match those of the statewide examinations. But it is extremely important to note that the current use of simplified multiple tiered questions as seen on the LER may not support the goals of the No Child Left Behind Act or the Elementary and Secondary Education Act (ESEA) which still promote and allow standardized, annual achievement tests to measure learning and to revise teaching practices for high school science students in the United States of America. The findings of this study suggests that even with years of testing reform, NYS currently uses inadequate measures to assess achievement in the secondary science classroom.

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Appendix I

Living Environment Core Curriculum Guide Photosynthesis/Respiration

Standard 4; Key Idea 5:

Organisms maintain a dynamic equilibrium that sustains life.

Life is dependent upon availability of an energy source and raw materials that are used in the basic enzyme-controlled biochemical processes of living organisms. These biochemical processes occur within a narrow range of conditions. Because organisms are continually exposed to changes in their external and internal environments, they must continually monitor and respond to these changes. Responses to change can range in complexity from simple activation of a cell chemical process to elaborate learned behavior. The result of these responses is called homeostasis, a “dynamic equilibrium” or “steady state” which keeps the internal environment within certain limits. Organisms have a diversity of homeostatic feedback mechanisms that detect deviations from the normal state and take corrective actions to return their systems to the normal range. These mechanisms maintain the physical and chemical aspects of the internal environment within narrow limits that are favorable for cell activities. Failure of these control mechanisms can result in disease or even death. Explain the basic biochemical processes in living organisms and their importance in maintaining dynamic equilibrium.

PERFORMANCE INDICATOR 5.1 - Major Understandings

5.1a The energy for life comes primarily from the Sun. Photosynthesis provides a vital connection between the Sun and the energy needs of living systems.

5.1b Plant cells and some one-celled organisms contain chloroplasts, the site of photosynthesis. The process of photosynthesis uses solar energy to combine the inorganic molecules carbon dioxide and water into energy-rich organic compounds (e.g., glucose) and release oxygen to the environment.

5.1c In all organisms, organic compounds can be used to assemble other molecules such as proteins, DNA, starch, and fats. The chemical energy stored in bonds can be used as a source of energy for life processes.

5.1d In all organisms, the energy stored in organic molecules may be released during cellular respiration. This energy is temporarily stored in ATP molecules. In many organisms, the process of cellular respiration is concluded in mitochondria, in which ATP is produced more efficiently, oxygen is used, and carbon dioxide and water are released as wastes.

5.1e The energy from ATP is used by the organism to obtain, transform, and transport materials, and to eliminate wastes.

5.1f Biochemical processes, both breakdown and synthesis, are made possible by a large set of biological catalysts called enzymes. Enzymes can affect the rates of chemical change. The rate at which enzymes work can be influenced by internal environmental factors such as pH and temperature.

5.1g Enzymes and other molecules, such as hormones, receptor molecules, and antibodies, have specific shapes that influence both how they function and how they interact with other molecules.

Appendix II

Living Environment Core Curriculum Guide Genetics

Standard 4 -Key Idea 2:

Organisms inherit genetic information in a variety of ways that result in continuity of structure and function between parents and offspring.

Organisms from all kingdoms possess a set of instructions (genes) that determines their characteristics. These instructions are passed from parents to offspring during reproduction. Students are familiar with simple mechanisms related to the inheritance of some physical traits in offspring. They are now able to begin to understand the molecular basis of heredity and how this set of instructions can be changed through recombination, mutation, and genetic engineering.

The inherited instructions that are passed from parent to offspring exist in the form of a code. This code is contained in DNA molecules. The DNA molecules must be accurately replicated before being passed on. Once the coded information is passed on, it is used by a cell to make proteins. The proteins that are made become cell parts and carry out most functions of the cell.

Throughout recorded history, humans have used selective breeding and other biotechnological methods to produce products or organisms with desirable traits. Our current understanding of DNA extends this to the manipulation of genes leading to the development of new combinations of traits and new varieties of organisms.

PERFORMANCE INDICATORS 2.1- Major Understandings

Explain how the structure and replication of genetic material result in offspring that resemble their parents.

Major Understandings

2.1a Genes are inherited, but their expression can be modified by interactions with the environment.

2.1b Every organism requires a set of coded instructions for specifying its traits. For offspring to resemble their parents there must be a reliable way to transfer information from one generation to the next. Heredity is the passage of these instructions from one generation to another.

2.1c Hereditary information is contained in genes, located in the chromosomes of each cell. An inherited trait of an individual can be determined by one or by many genes, and a single gene can influence more than one trait. A human cell contains many thousands of different genes in its nucleus.

2.1d In asexually reproducing organisms, all the genes come from a single parent. Asexually produced offspring are normally genetically identical to the parent.

2.1e In sexually reproducing organisms, the new individual receives half of the genetic information from its mother (via the egg) and half from its father (via the sperm). Sexually produced offspring often resemble, but are not identical to, either of their parents.

2.1f In all organisms, the coded instructions for specifying the characteristics of the organism are carried in DNA, a large molecule formed from subunits arranged in a sequence with bases of four kinds (represented by A, G, C, and T). The chemical and structural properties of DNA are the basis for how the genetic information that underlies heredity is both encoded in genes (as a string of molecular “bases”) and replicated by means of a template.

2.1g Cells store and use coded information. The genetic information stored in DNA is used to direct the synthesis of the thousands of proteins that each cell requires.

2.1h Genes are segments of DNA molecules. Any alteration of the DNA sequence is a mutation. Usually, an altered gene will be passed on to every cell that develops from it.

2.1i The work of the cell is carried out by the many different types of molecules it assembles, mostly proteins. Protein molecules are long, usually folded chains made from 20 different kinds of amino acids in a specific sequence. This sequence influences the shape of the protein. The shape of the protein, in turn, determines its function.

2.1j Offspring resemble their parents because they inherit similar genes that code for the production of proteins that form similar structures and perform similar functions.

2.1k The many body cells in an individual can be very different from one another, even though they are all descended from a single cell and thus have essentially identical genetic instructions. This is because different parts of these instructions are used in different types of cells, and are influenced by the cell’s environment and past history.

PERFORMANCE INDICATORS 2.2- Major Understandings

Explain how the technology of genetic engineering allows humans to alter genetic makeup of organisms.

Major Understandings

2.2a For thousands of years new varieties of cultivated plants and domestic animals have resulted from selective breeding for particular traits.

2.2b In recent years new varieties of farm plants and animals have been engineered by manipulating their genetic instructions to produce new characteristics.

2.2c Different enzymes can be used to cut, copy, and move segments of DNA. Characteristics produced by the segments of DNA may be expressed when these segments are inserted into new organisms, such as bacteria.

2.2d Inserting, deleting, or substituting DNA segments can alter genes. An altered gene may be passed on to every cell that develops from it.

2.2e Knowledge of genetics is making possible new fields of health care; for example, finding genes which may have mutations that can cause disease will aid in the development of preventive measures to fight disease. Substances, such as hormones and enzymes, from genetically engineered organisms may reduce the cost and side effects of replacing missing body chemicals.

Appendix III

Genetics Concept Map Wordlist

Mendelian Genetics

Dominant
Recessive
Hybrid/heterozygous
Homozygous
Punnett Square
Probability
Phenotype
Genotype
Physical
Allele
Crossing over
Gene
Gene linkage
Multiple alleles

Modern Genetics

DNA
RNA
Nucleotides
Base pairing
Adenine
Guanine
Tyrosine
Cytosine
Replication
Enzyme
mRNA
tRNA
rRNA
ribosome
protein synthesis
transcription
translation
codon
anticodons
mutation
RNA polymerase
Transgenic (organisms)
Genetic markers
Selective breeding
Genetic engineering
Restriction enzymes
Gel electrophoresis
Recombinant DNA
PCR (polymerase chain reaction)
Plasmid
Human Genome Project

Appendix IV

Concept Map Rubric

Mastery Level	Propositions (concepts)	Propositions (relationship/links)	Hierarchy
10 (100-91%)	Very high level of achievement; achievement exceeds the provincial standard Presence of 20 teacher concepts.	thorough, excellent • high degree of concept relationships (more than 30) • almost no errors • a wide variety of supported propositional statement in context	high degree of effectiveness in branching
9 (90-81%)	high level of achievement • achievement is <i>at</i> the provincial standard Presence of 18 teacher concepts.	very good • very good degree of concept relationships (more than 27) • almost no errors • a wide variety of supported propositional statement in context	considerable effectiveness in branching
8 (80-71%)	Good- moderate level of achievement • achievement is <i>at</i> the provincial standard Presence of 16 teacher concepts.	good • good degree of concept relationships (more than 24) • limited errors • a wide variety of supported propositional statement in context	effectiveness in branching
7 (70-61%)	moderate level of achievement • achievement is <i>below, but is approaching</i> the provincial standard Presence of 14 teacher concepts.	adequate • some degree of concept relationships (more than 20) • minimal variety of supported propositional statements in context • some errors or major omissions • simple purposes and limited contexts	Some effectiveness in branching
6 (60-51%)	limited level of achievement • achievement falls <i>below</i> the provincial standard Presence of 12 teacher concepts.	minimal, weak • low degree of concept relationships (more than 17) • many errors or omissions • low variety of supported propositional statement in context	Limited effectiveness in branching
5 (50-41%)	insufficient achievement of curriculum expectations • additional learning is required before the student will begin to achieve success with this grade's expectations Presence of 10 teacher concepts.	major errors or omissions • low degree of concept relationships (more than 14) • structured situations for simple purposes • major omissions	Not effective in branching
4 (40-31%)	Most scores would replicate scoring for 5, except greater degrees of omissions Presence of 8 teacher concepts.	Most scores would replicate scoring for 5, except greater degrees of omissions • low degree of concept relationships (more than 11)	Not effective in branching
3 (30-21%)	Most scores would replicate scoring for 5. Presence of 6 teacher concepts.	Most scores would replicate scoring for 5, except greater degrees of omissions • low degree of concept relationships (more than 8)	Not effective in branching
2 (20-11%)	Most scores would replicate scoring for 5. Presence of 4 teacher concepts.	Most scores would replicate scoring for 5, except greater degrees of omissions • low degree of concept relationships (more than 5)	Not effective in branching
1 (10-0%)	Most scores would replicate scoring for 5. Presence of 2 teacher concepts.	Most scores would replicate scoring for 5, except greater degrees of omissions • low degree of concept relationships (more than 2)	Not effective in branching

Appendix V

Living Environment ADV

What do you know about Photosynthesis/Respiration?

Instructions to Students

The following pages contain **15** questions about photosynthesis/respiration in living things. Each question has two parts: A **Multiple Choice Response** followed by a **Multiple Choice Reason**. You are asked to make one choice from **both** the **Multiple Choice Response** section and one choice from the **Multiple Choice Reason** section for each question.

If you have another reason for your answer than one that is listed, write in the space provided as well as making the choice letter in the reason box.

ANSWER ALL QUESTIONS on the SEPARATE ANSWER SHEET

1. Read each question carefully.
2. Take time to calculate and consider your answer.
3. Record your answer in the correct box on the answer sheet.
Ex. #1. Reason
4. Record your answer in the correct *reason* box on the answer sheet.
Ex. #1. Reason
5. If you wish to provide your own reason for the question, write this on the answer sheet in the space provided. Leave the first reason line blank.
Ex. #1. Reason _____ _____

Don't forget to record your heading information on your Answer Sheet!!!

Name: _____
Class: Living Environment (ADV) –per. ____
Age: _____

Free Response ANSWER SHEET
What do you know about Photosynthesis and Respiration?

1. _____ Reason _____ _____
2. _____ Reason _____ _____
3. _____ Reason _____ _____
4. _____ Reason _____ _____
5. _____ Reason _____ _____
6. _____ Reason _____ _____
7. _____ Reason _____ _____
8. _____ Reason _____ _____
9. _____ Reason _____ _____
10. _____ Reason _____ _____
11. _____ Reason _____ _____
12. _____ Reason _____ _____
13. _____ Reason _____ _____
14. _____ Reason _____ _____
15. _____ Reason _____ _____

Appendix VI

PHOTOSYNTHESIS AND RESPIRATION DIAGNOSTIC INSTRUMENT (odd numbered questions)

1. What gas is given out in largest amounts by green plants in the presence of sunlight?

- 1) Carbon dioxide
- 2) Oxygen

The reason for my answer is because:

- a. This gas is given off in the presence of light energy because green plants only respire during the day.
- b. This gas is given off by green plants because green plants only photosynthesize and do not respire in the presence of light energy.
- c. There is more of this gas produced by the green plant during photosynthesis than is required by the green plant for respiration and other processes, so the excess is given off.
- d. This gas is a waste product given off by green plants after they photosynthesize.
- e. _____

3. Which gas is given off by green plants in large amounts when there is no light energy at all?

- 1) Carbon dioxide gas
- 2) Oxygen gas

The reason for my answer is because:

- a. Green plants stop photosynthesizing when there is no light energy at all so they continue to respire and therefore they give off this gas.
- b. This gas is given off by the green plant during photosynthesis which takes place when there is no light energy.
- c. Since green plants respire only when there is no light energy they give off this gas.
- d. _____

5. Respiration in plants takes place in:

- 1) The cells of the roots only.
- 2) Every plant cell.
- 3) The cells of the leaves only.

The reason for my answer is because:

- a. All living cells need energy to live.
- b. Only leaves have special pores (stomata) to exchange gas.
- c. Only roots have small pores to breathe.
- d. Only roots need energy to absorb water.
- e. _____

7. Which of the following is the most accurate statement about respiration in green plants?

- 1) It is a chemical process by which plants manufacture food from water and carbon dioxide.

- 2) It is a chemical process in which energy stored in food is released using oxygen.
- 3) It is the exchange of carbon dioxide and oxygen gases through plant stomata.
- 4) It is a process that does not take place in green plants when photosynthesis is taking place.

The reason for my answer is because:

- a. Green plants never respire they only photosynthesize.
- b. Green plants take in carbon dioxide and give off oxygen when they respire.
- c. Respiration provides the green plant with energy to live.
- d. Respiration only occurs in green plants when there is no light energy.
- e. _____

9. Which of the following equations best represents the process of respiration in plants?

- 1) Glucose + oxygen \longrightarrow energy + carbon dioxide + water.
- 2) Carbon dioxide + water \longrightarrow energy + glucose + oxygen.
- 3) Carbon dioxide + water $\xrightarrow{\text{light energy}}$ oxygen + glucose.
Chlorophyll
- 4) Glucose + oxygen \longrightarrow carbon dioxide + water.

The reason for my answer is because:

- a. During respiration green plants take in carbon dioxide and water in the presence of light energy to form glucose.
- b. Carbon dioxide and water are used by the green plant to produce energy during which time glucose and oxygen waste are produced.
- c. During respiration, green plants take in oxygen and give off carbon dioxide and water.
- d. During respiration, green plants derive energy from glucose using oxygen.
- e. _____

11. Which of the following factors is not important for the process of photosynthesis?

- 1) Amount of oxygen.
- 2) Amount of carbon dioxide.
- 3) Amount of chlorophyll.
- 4) Amount of light.

The reason for my answer is because:

- a. Photosynthesis can take place with no light energy.
- b. Non green plants like fungi which do not contain chlorophyll or similar pigments can also photosynthesize.
- c. Photosynthesis cannot take place without carbon dioxide.
- d. Oxygen is not required for photosynthesis; it is a by-product of photosynthesis.
- e. _____

13. Which of the following comparisons between the processes of photosynthesis and respiration in green plants is correct?

Photosynthesis

- 1) Takes place in green plants only.
- 2) Takes place in all plants.
- 3) Takes place in green presence of light energy.
- 4) Takes place in green plants in the presence of only light energy.

Respiration

- Takes place in animals only.
- Takes place only in all animals.
- Takes place in all plants and in all animals at all times.
- Takes place in all plants when there is no light energy and all the time in all animals.

The reason for my answer is because:

- a. Green plants photosynthesize and do not respire at all.
- b. Green plants photosynthesize during the day and respire at night (when there is no light energy at all).
- c. Respiration is continuous in all living things. Photosynthesis occurs only when light energy is available.
- d. Plants respire when they cannot obtain enough energy from photosynthesis (e.g. at night) and animals respire continuously because they cannot photosynthesize.
- e. _____

15. Which metabolic process is responsible for the muscle fatigue and cramping an athlete may experience after running a race:

- 1) alcoholic fermentation
- 2) aerobic respiration
- 3) dehydration synthesis
- 4) lactic acid fermentation

The reason for my answer is because:

- a. Pyruvic acid that accumulates as a result of glycolysis is converted to a byproduct of fermentation in the muscle tissue. This causes a painful, burning sensation.
- b. Ethyl alcohol and carbon dioxide are made in the muscle tissue as a result of fermentation. This causes a painful, burning sensation.
- c. All living cells use energy. As the energy is used up we feel pain and cramping in the muscle tissue.
- d. _____

Reference:

Haslam, F., & Treagust, D.F. (1987). Diagnosing secondary students' misconceptions of photosynthesis and respiration in plants using a two-tier multiple choice instrument. *Journal of Biological Education*, 21 (3), 203-211.

Professor David F. Treagust
Science and Mathematics Education Centre
Curtin University of Technology
GPO Box U1987
Perth WA 6845

Appendix VII

Living Environment ADV What do you know about Genetics?

Instructions to Students

The following pages contain **14** questions about Genetics in living things. Each question has two parts: A **Multiple Choice Response** followed by a **Multiple Choice Reason**. You are asked to make one choice from **both** the **Multiple Choice Response** section and one choice from the **Multiple Choice Reason** section for each question.

If you have another reason for your answer than one that is listed, write in the space provided as well as making the choice letter in the reason box.

ANSWER ALL QUESTIONS on the SEPARATE ANSWER SHEET

6. Read each question carefully.

7. Take time to calculate and consider your answer.

8. Record your answer in the correct box on the answer sheet.

Ex. #1. Reason

9. Record your answer in the correct *reason* box on the answer sheet.

Ex. #1. Reason

10. If you wish to provide your own reason for the question, write this on the answer sheet in the space provided. Leave the first reason line blank.

Ex. #1. Reason _____ _____

Don't forget to record your heading information on your Answer Sheet!!!

Name: _____
Class: Living Environment (ADV) –per. ____
Age: _____

Free Response ANSWER SHEET
What do you know about Genetics?

1. _____ Reason _____ _____
2. _____ Reason _____ _____
3. _____ Reason _____ _____
4. _____ Reason _____ _____
5. _____ Reason _____ _____
6. _____ Reason _____ _____
7. _____ Reason _____ _____
8. _____ Reason _____ _____
9. _____ Reason _____ _____
10. _____ Reason _____ _____
11. _____ Reason _____ _____
12. _____ Reason _____ _____
13. _____ Reason _____ _____
14. _____ Reason _____ _____
15. _____ Reason _____ _____

Appendix VIII

Genetics Diagnostic Examination (even numbered questions)

2. In mice, the gene allele *b* for white skin is recessive to *B* for brown skin. A male mouse with genotype *Bb* was mated to a female mouse with the genotype *bb* and then gave birth to a litter of 12 mice. How many mice in the litter are expected to be white?
- 3
 - 6
 - 12
 - Don't know

The reason for my answer is because:

- Half of the sperms but all the eggs carry the *b* allele.
 - All the sperms but half of the eggs carry the *b* allele.
 - There is only one possible fertilization event.
 - _____
4. Paul is an albino who was born without the ability to make a pigment in the skin. Albinism is a recessive characteristic. Suppose we use "A" for the dominant gene (allele) and "a" for the recessive gene, what would be Paul's genotype for albinism?
- AA or Aa
 - Aa or aa
 - aa
 - Don't know

The reason for my answer is because:

- Paul must have at least one recessive allele "a".
 - Paul must have at least one dominant allele "A".
 - One recessive allele "a" does not make Paul an albino.
 - Recessive allele "a" is only expressed in Paul when present in "Aa" form.
6. Within which cell type, will a mutation mostly likely be passed on to an individual's offspring?
- Gametes
 - Somatic cells
 - Liver cells

The reason for my answer is because:

- Sex cells contain hereditary information.
- Somatic cells are diploid and all human cells are diploid.
- The liver is used as a detoxifier and could correct a mutation if it occurs.

- d. _____
8. An arctic fox changes color from white to tan (brown) during the spring/summer months. The best explanation for the differences in color is that the gene regulating coat color is
1. Influenced by genetic engineering
 2. Influenced by selective breeding
 3. Influenced by linked genes on homologous chromosomes
 4. Influenced by environmental conditions

The reason for my answer is because:

- a. Humans can manipulate any traits after the completion of the Human Genome Project.
- b. Temperature changes influence protein expression.
- c. Random acts cause changes in the genetic material of organisms.
- d. _____

10. A human male is colorblind, and his wife is heterozygous for the colorblind trait. The probability that his daughters will be colorblind is 50%. Which sex chromosome has the father contributed to his daughters?
1. X
 2. Y
 3. Neither

The reason for my answer is because:

- a. Males can only contribute a colorblind allele/chromosome to their sons.
- b. Males can only contribute a colorblind allele/chromosome to their daughters.
- c. Males can contribute colorblind allele/chromosomes to either sons or daughters.
- d. _____

12. Some dogs bark when following a scent, others are silent and are called silent trackers. Barking is dominant (allele B) to non-barking (allele b). A hunter owns a barker that he wants to use for breeding purposes. However, he wants to be sure it has a genotype of BB. What is the genotype of the female dog he should mate with this dog?
1. BB
 2. Bb
 3. bb

The reason for my answer is because:

- a. If any silent tracker appears in the offspring, the hunter can be sure that his dog's genotype is Bb.
- b. If no silent trackers appear in the offspring, he can be sure that his dog's genotype is BB.
- c. If the dog is Bb, the chances of getting silent trackers in the offspring are zero.

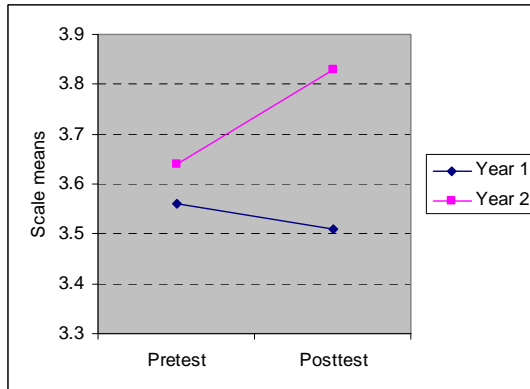
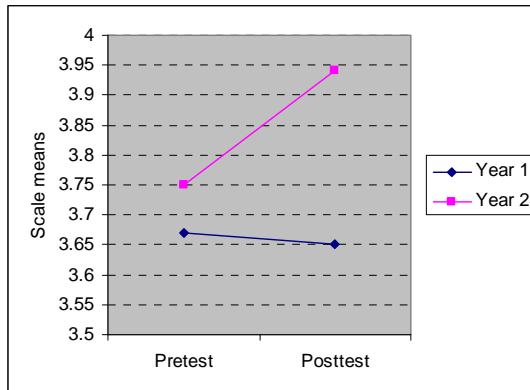
14. In the 1950's, Fred Sanger successfully found that insulin protein consists of 51 amino acids arranged in a specific order. With this information, do you think it was possible for Sanger to determine the information of the insulin gene or the DNA base sequence (ex. In terms of A, T, C, or G) of the gene?
1. Yes.
 2. No.
 3. Don't know.

The reason for my answer is because:

- a. DNA and insulin molecules are structurally different.
- b. The sequence of DNA bases in the insulin gene and that of the amino acids or subunits in the insulin (protein) molecule are different.
- c. The sequence of DNA bases in the insulin gene corresponds to that of the amino acids or subunits of the insulin (protein) molecule.

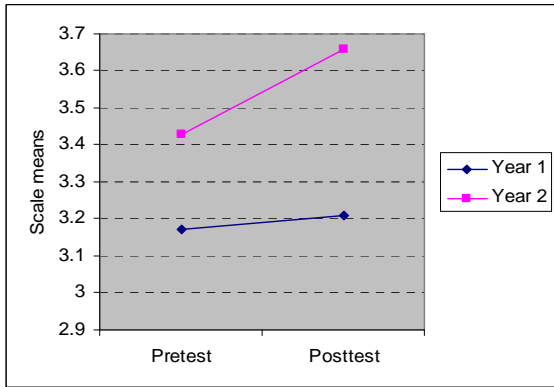
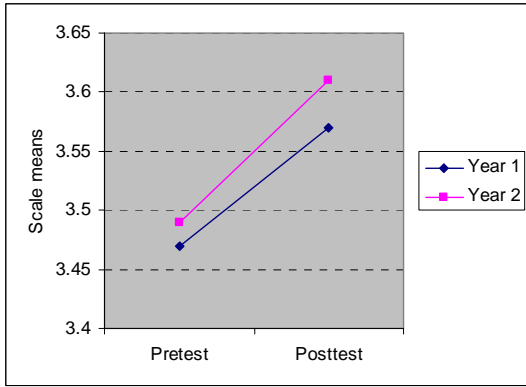
Appendix IX

Graphical Illustrations of TOSRA pretest/posttest

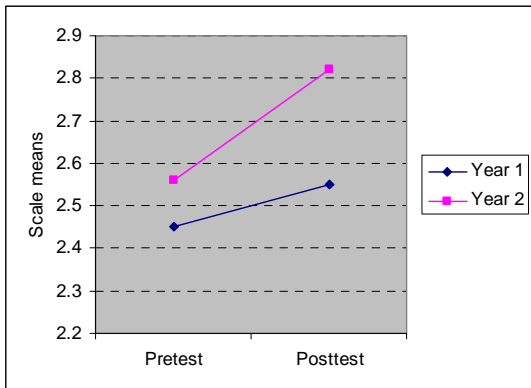
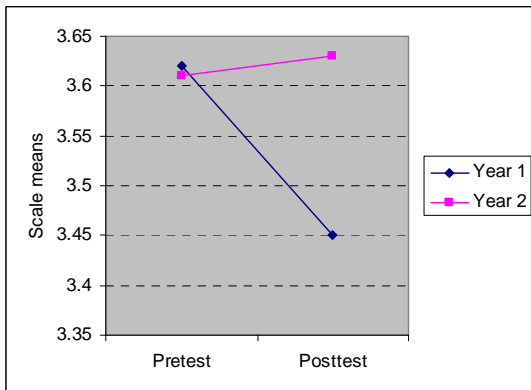


TOSRA Social Implications of Science scale
(Years 1 & 2 pretest-posttest differences)

TOSRA Adoption of Scientific Attitudes scale
(Years 1 & 2 pretest-posttest differences)



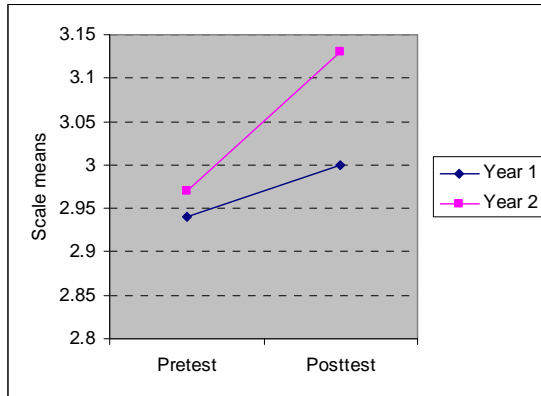
TOSRA Normality of Scientists scale Figure 19. TOSRA Enjoyment of Science (Years 1 & 2 pretest-posttest differences) Lessons scale (Years 1 & 2 pretest-posttest differences)



**TOSRA Attitude to Scientific Inquiry scale
(Years 1 & 2 pretest-posttest differences)**

**TOSRA Leisure Interest in Science scale
(Years 1 & 2 pretest-posttest differences)**

Graphical Illustrations of TOSRA pretest/posttest (CONT.)

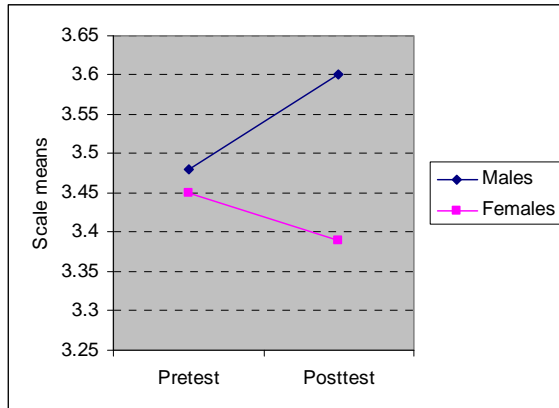


**TOSRA Career Interest in Science scale
(Years 1 & 2 pretest-posttest differences)**

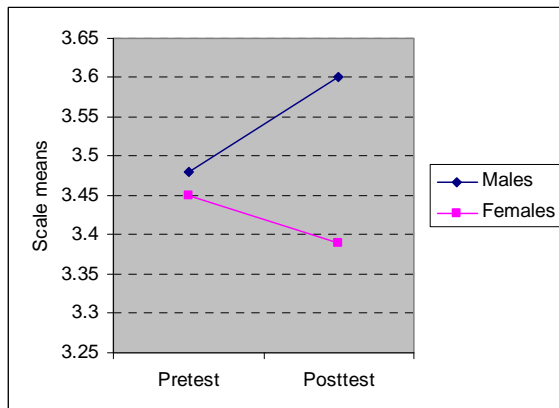
Appendix X

Graphical Illustrations of TOSRA gender analyses

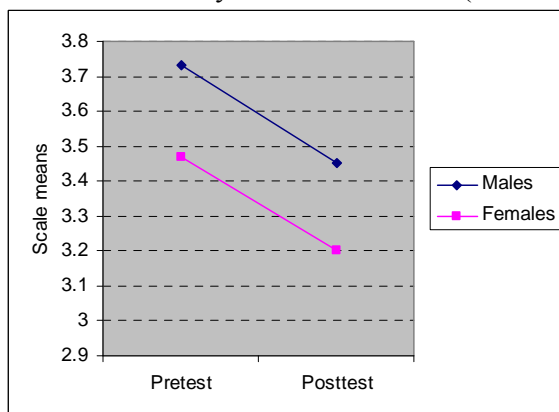
YEAR 1



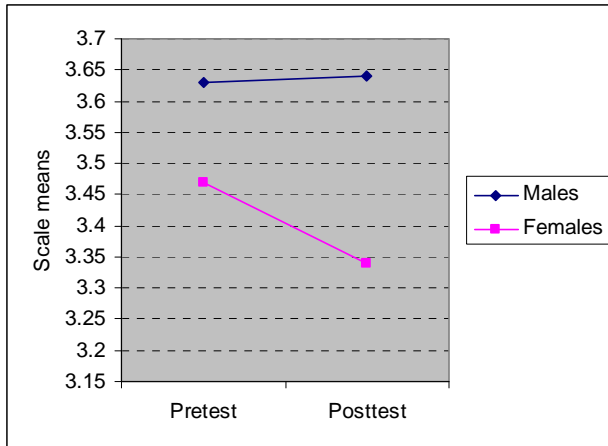
TOSRA Social Implications of Science scale (Year 1 pretest-posttest gender differences)



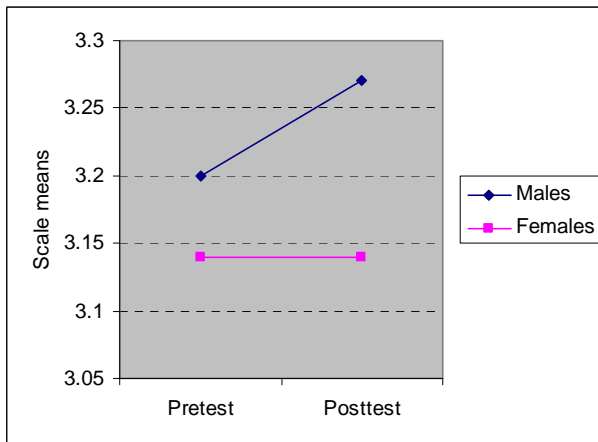
TOSRA Normality of Scientists scale (Year 1 pretest-posttest gender differences)



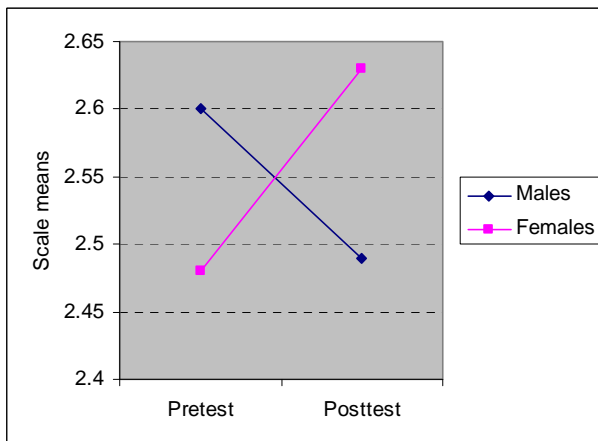
TOSRA Attitude to Scientific Inquiry scale (Year 1 pretest-posttest gender differences)



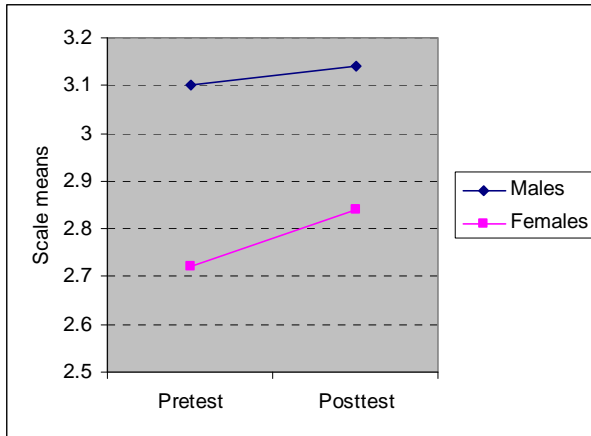
TOSRA Adoption of Scientific Attitudes scale (Year 1 pretest-posttest gender differences)



TOSRA Enjoyment of Science Lessons scale (Year 1 pretest-posttest gender differences)

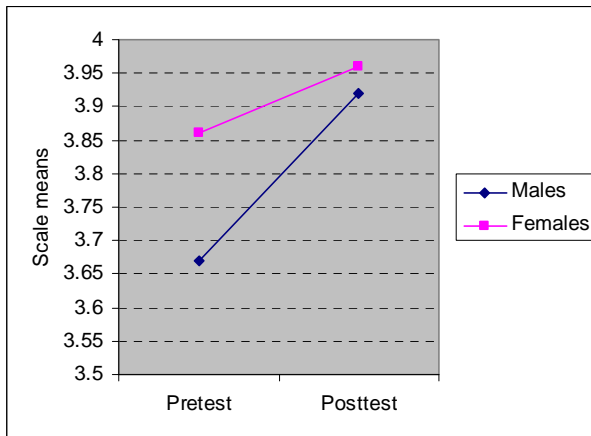


TOSRA Leisure Interest in Science scale (Year 1 pretest-posttest gender differences)

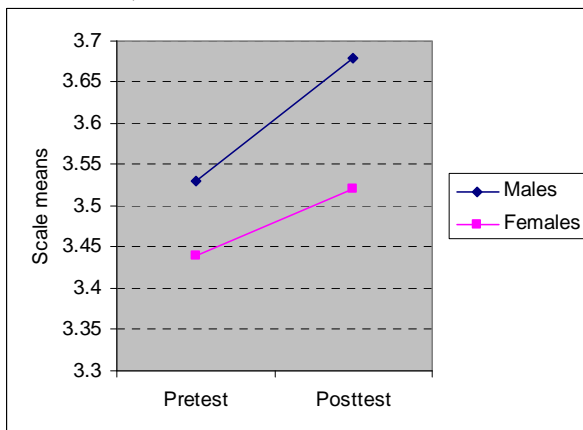


TOSRA Career Interest in Science scale (Year 1 pretest-posttest gender differences)

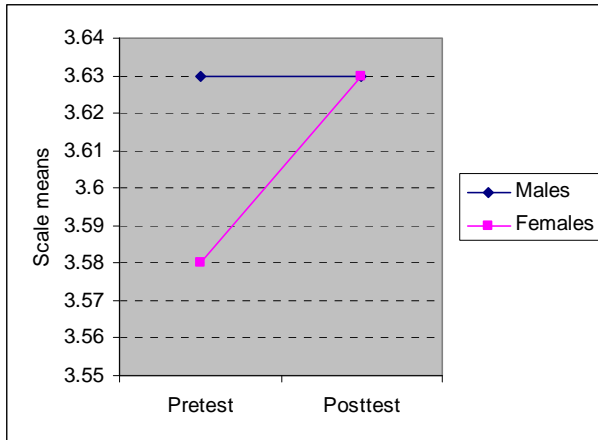
YEAR 2



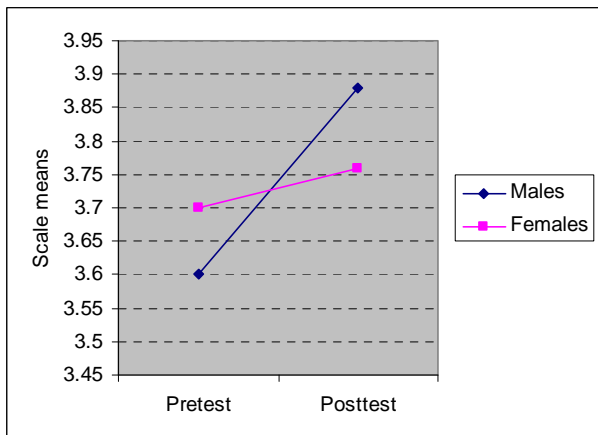
TOSRA Social Implications of Science scale (Year 2 pretest-posttest gender differences)



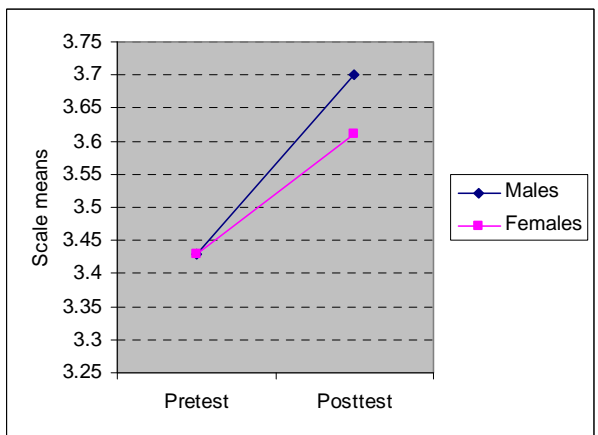
TOSRA Normality of Scientists scale (Year 2 pretest-posttest gender differences)



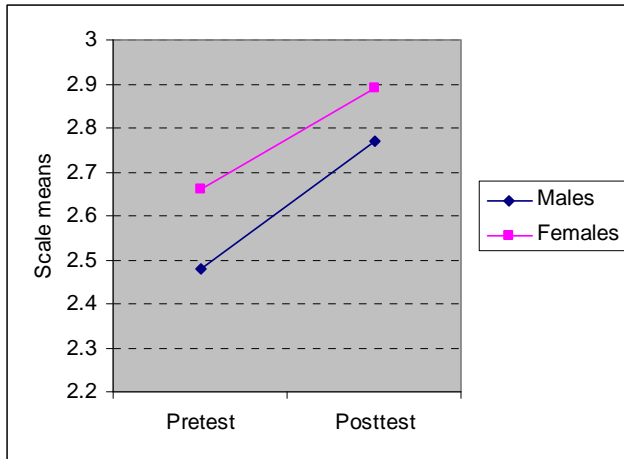
TOSRA Attitude to Scientific Inquiry scale (Year 2 pretest-posttest gender differences)



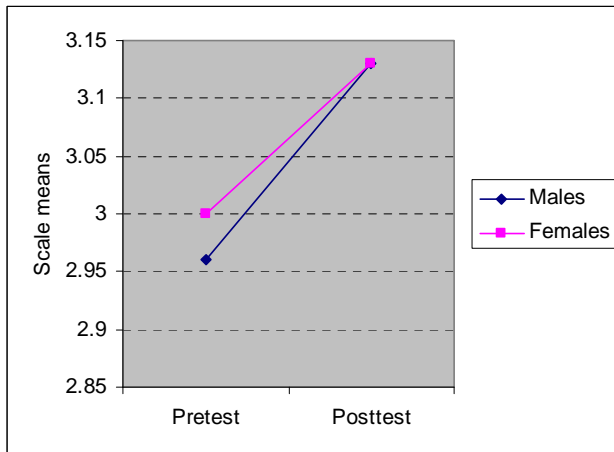
TOSRA Adoption of Scientific Attitudes scale (Year 2 pretest-posttest gender differences)



TOSRA Enjoyment of Science Lessons scale (Year 2 pretest-posttest gender differences)



TOSRA Leisure Interest in Science scale (Year 2 pretest-posttest gender differences)



TOSRA Career Interest in Science scale (Year 2 pretest-posttest gender differences)

Appendix XI

One Student Interview (Questions & Answers)

Post- Standardized and Diagnostic Two-Tier Exams Photosynthesis, Respiration, and Genetics

1. How helpful were the use of concept maps in your understanding of P/R/G?
“Concept maps were good but it was hard to get it, but when laid out in front of you, it makes good connections between things”
2. Which tools (activities) used by the teacher, if any, helped you to understand the ideas tested in P/R/G?
“Write your own notes, I like that I have to think for myself and not just copy notes”
3. Did you enjoy learning about P/R/G? What did you enjoy?
“No, I like circulator system better than photosynthesis. I don’t want to learn about plants, I want to learn about the human body”. “I like genetics technology, switching genes and it makes me think of other topics and draws connections to other units”.
4. Do you now understand more about P/R/G as compared to your previous experiences regarding P/R/G?
“I understand it more now, because it went more in depth”. “In 7th grade it was just memorize everything but in 9th grade you have to think and know what stuff actually means. You need to know, what you believe is happening”. “I understand more now, because previously it wasn’t required to know. It wasn’t the basis of learning in 7th grade, it was very basic”.
5. Is P/R/G difficult to learn? Why?
“Yes, once you get lost, it is difficult to catch up and understand everything, too many words to know”.
6. Were Internet movie clips, interactive Internet web sites, concept maps, homework assignments, laboratory activities, etc. useful in your understanding of P/R/G? What helped the most?
“Video clips helped me to learn stuff, like the labs, the one where we had to cut the DNA and the Tony lab”. “Homework, concept maps, and video’s helped the most”.
7. Please answer the following questions regarding P/R/G:
 - a. What is a sex-linked disorder? How can we identify it? *“Turner’s Disease – sex linked”*. After prodding the student (How can we identify it?) corrected the statement. *“Turner’s Disease is caused by a mutation that is not sex linked, by caused by an additional X chromosome”*.
Using a pedigree regarding sex-linked diseases, what could we learn?
“It tells us whether we should have children or not. A pedigree will help in diagnosing colorblindness for example”.
Could it be fixed using genetic engineering?
“No, sex-linked disease can’t be fixed because they are in sex chromosomes and you would have to fix them before the child was born.”

- b. Do plants complete respiration, photosynthesis, or both? Why did you choose your answer?
“Both, plants do photosynthesis during the day when there is light, but respiration during the night when they have no light.” After some prodding (Teacher asked: Why do plants need to do respiration?) the student corrected the above statement to include *“Photosynthesis is during the day and night, so is respiration”*.
8. Did you think the information learned regarding P/R/G is useful to you? How does it help you? (Outside of school)
“I guess it is good to know, you can always use information about something you don’t know”.
9. Did the two-tier diagnostic (reasoning) exam and the multiple choice (standardized) exams accurately assess what you know about P/R/G? Which exam do you feel best represents a test of what you know regarding P/R/G?
“Multiple choices you can guess and be lucky, but diagnostic you will probably get caught, diagnostics test should be used as a review, it helped when I figured out what I don’t know”. *“In addition, reasoning sections are better because you have to know why the first answer was right, because sometimes you can guess between two answers on the multiple choice and you have a good chance of getting the answer correct”*.
10. Did anyone task you completed this year help in your understanding of P/R/G? Explain your answer.
“You were telling us not to copy all of your notes but to put them in your own words”. *“The lessons weren’t boring, we were allowed to discuss and debate stuff, not only do class work and memorize even though it was harder”*.