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Assimilative domain proficiency and performance in chemistry coursework

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This is to certify that the doctoral study by

Scott William Byrnes

has been found to be complete and satisfactory in all respects,
and that any and all revisions required by
the review committee have been made.

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Walden University
2010

ABSTRACT

Assimilative Domain Proficiency and Performance in Chemistry Coursework

By

Scott William Byrnes

M.S., Nova Southeastern University, 1996
B.S., Hawaii Loa College, 1992

Dissertation Submitted in Partial Fulfillment
Of the Requirements for the Degree of
Doctor of Education Specialization in Teacher Leadership

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ABSTRACT

The assimilation and synthesis of knowledge is essential for students to be successful in chemistry, yet not all students synthesize knowledge as intended. The study used the Learning Preference Checklist to classify students into one of three learning modalities – visual, auditory, or kinesthetic (VAK). It also used the Kolb Learning Style Inventory (KLSI), which utilizes four learning domains - Converging, Accommodating, Diverging, and Assimilating - to explain the students' maturation process by showing shift from any domain towards the Assimilating domain. A shift approaching this domain was considered as improvement in the assimilation and synthesis of knowledge. This pre-experimental one-group pretest-posttest study was used to test the hypothesis that modifying a high school chemistry curriculum to accentuate a student's learning preference would result in a shift towards the Assimilative domain on the KLSI and if there was a correlation between the improvement in student learning and a shift towards the KLSI Assimilating domain. Forty-two high school students were issued the VAK and provided with differentiated instruction via homologous cooperative learning groups. Pre- and post- KLSI and chemistry concepts tests were administered. *T* test analyses showed no significant shift towards the Assimilating domain. Further Pearson's *r* analyses showed no significant correlation between the KLSI and exam scores. This study contributes to social change by providing empirical evidence related to the effectiveness infusing learning styles into the science curriculum and the integration of the KLSI to monitor cognitive development as tools in raising standardized test scores and enhancing academic achievement. Results from the study can also inform future research into learning styles through their incorporation into the science curriculum.

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DEDICATION

This work is dedicated to my parents, Mr. and Mrs. Bill and Sandy Byrnes. It was your work ethic and encouragement that instilled in me the desire to do my best. I also thank you for allowing me to broaden my horizons and showing support for my choices. I would also like to further dedicate this to my daughter, Sophie. I know I was not able to spend as much quality time with you as I wanted during the past three years, but this will now change. Lastly, the most important dedication goes to my wife, Micki. Thank you for correcting my grammar mistakes and editing my papers early on. Moreover, thank you for putting up with me during this entire process and being my partner.

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I would like to thank Jim Nigrelli for his guidance and assistance throughout the years. It was because of the example that you set that I was able to grow as a teacher. I know that if I had decided to teach anywhere else, I would not have been able to accomplish as much as I have or have the knowledge base in the field of chemistry that I do now.

I would also like to thank Karly Wortman Good. In the early stages of this process, you were able to help me sort through some issues and concepts when my mind was becoming cluttered and overwhelmed.

Finally like to thank committee members. Dr. Barry Persky, I thank you for your guidance. Dr. Jolly, I thank you for your guidance, support, and assistance throughout this entire process (since the first class). You were always able to accommodate my needs, especially through the dissertation process and soothe my anxieties when it was necessary.

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CHAPTER 1:

THE PROBLEM

Introduction

For most students of high school age, chemistry is probably one of the hardest classes in which they will enroll. It requires an exceptionally high level of new vocabulary, math skills, and reading comprehension, as well as the ability to put these parts together for problem solving purposes. Success requires students to assimilate and synthesize knowledge which are high order thinking processes as opposed to rote memorization. Much of what a "given student learns…is governed in part by that student's native ability [to perform at a higher level of thinking], prior preparation but also the compatibility of …attributes as a learner and the instructor's teaching style" (Felder & Brent, 2005, p. 57); however, mismatches commonly exist between the perceived learning styles of the students and the method of delivery of the instructor (Felder & Brent, 2005; Felder & Spurlin, 2005). The failure to acknowledge, understand, and accommodate for differences in individual learning style can result in discouragement in the subject matter being taught (Felder & Spurlin, 2005).

Nature of the Problem

The central issue regarding teaching and learning styles is understanding the process by which students learn and apply scientific concepts. The science curriculum standards in Georgia prior to the fall of 2005 were based on an objective-based curriculum known as the Quality Core Curriculum (QCC). The QCC objectives were a "checklist of concepts to be covered by teachers" and "did not measure the depth of knowledge that students attained while learning the concepts" (Fulton County Schools, 2007, p. 1). In the fall of 2005, the state of Georgia underwent a paradigm shift by implementing a new science curriculum called the new Georgia Performance Standards (GPS), which are still in effect today. The GPS are meant to engage students on a more rigorous level by allowing teachers to explore integrated concepts in much greater depth. As a part of the new standards implementation, teachers will have to rely on fewer presentations and lectures and focus their instructional strategies on authentic assessment methodologies by leading more frequent open-ended investigations to help develop a student's problem-solving ability (Georgia Department of Education, 2007).

Problem Statement

Based upon broad-scale analysis, there is an identifiable gap between standardized test results (state and national) and the experience students at the Local Area High School (LAHS) have in transitioning from the old objective-based curriculum to GPS practice. Yet a press release by the Georgia Department of Education (2006) states that the Thomas B. Fordham Institute has rated Georgia's newly implemented GPS curriculum fifth in the nation. More so, the science standards have received an overall grade of "B," which is up from an "F" in 2000. Given this information, it would be reasonable to assume that transforming the curriculum has passed the scrutiny litmus test.

As with most issues concerning the development of cognitive abilities (and the transforming of a curriculum), one must be aware that mismatches commonly exist between the learning styles of the students in question and their teachers (Felder & Brent, 2005; Felder & Spurlin, 2005). Mather and Champagne (2008) stated that "teachers with an understanding of students' approach to learning can better adjust their own methods appropriately" (p. 7). Modifying instructional methodologies by accentuating individual learning preferences in this manner can lead to increased standardized test scores and a greater understanding of the conceptual constructs of the class.

Although the state of Georgia has provided a path to action with the implementation of the GPS standards, the responsibility for transitioning the students to this new method ultimately lies with the teacher. Although outside professional development opportunities may help, in many cases these chances are not widely available. Perhaps the focus should lie in monitoring the developmental progression of students as they transition through science courses rather than waiting for scores on a state-mandated test at the end of the semester or school year.

While there are many models and educational surveys that offer suggestions on how to address the developmental progression of students, two show greater promise in addressing the learning needs of the science student: (a) The Learning Preference Checklist (O'Brien, 1990), which classifies student learning preference in three *modalities* – visual, auditory, and kinesthetic (VAK) – and the (b) Kolb Learning Style Inventory (KLSI) (Kolb, 2005) which explains the cyclical maturation of the learning process.

The VAK model can be utilized to assist in incorporating different learning techniques into classroom instruction and activities. The KLSI can determine the learning dimension of the student and assist in establishing connections which help link knowledge of the concepts with prior experiences. When both models are used in conjunction with one another, students will promote their advancement into the critical thinking realm, which is the region where standards-based test questions are concentrated.

Spurred by the changing of Georgia's science curriculum into one that concentrates on conceptual development and application, this researcher determined if enhancing the new curriculum by providing instruction incorporating the VAK model will affect a shift in the learning preference towards the Assimilative domain – a region of development most commonly held by undergraduate chemistry majors (Kolb, 1984, p. 86) according to the KLSI (Kolb, 2005). This will be accomplished by specifically linking *differentiated instruction* to the three *learning modalities* – visual, auditory, and kinesthetic – according to Lynn O'Brien's (1990) Learning Preference Checklist. Doing so will efficiently modify the approach students take to solving chemistry problems of increased conceptual complexity and rigor, with a secondary resultant factor being increased classroom success in the subject matter.

Nature of the Study

The experimental design utilized to determine the effectiveness of the transformation from objective-based instructional practices to that of Georgia's new standards-based GPS curriculum in the field of chemistry followed the preexperimental one-group pretest-posttest design (ex: Group A: O_1—X—O_2) as described by Creswell (2003, pp. 167-169). In this method, a researcher studies a single group without the aid of a control group as a means of comparison (pp. 167-169). As a part of the experimental design, the chemistry curriculum was differentiated by content, process, and student readiness according to each student's preferred learning modality according to O'Brien's Learning Preference Checklist (1990). Flexible scaffolding on unit content was utilized as a problem-based learning (PBL) strategy to assist students with developing skills to become better self-directed learners.

Research Questions and Hypothesis

The study is based on the following comparison and correlation research questions and hypotheses.

Research Question 1

Can modifying high school chemistry curriculum to accentuate a student's learning preference affect a shift towards the Assimilative domain according to the Kolb Learning Style Inventory?

Null Hypothesis 1

Modifying a high school chemistry curriculum to accentuate a student's learning preference will not affect a significant shift towards the Assimilative domain according to the Kolb Learning Style Inventory.

Alternative Hypothesis 1

Modifying a high school chemistry curriculum to accentuate a students learning preference will affect a shift towards the Assimilative domain according to the Kolb Learning Style Inventory.

Research Question 2

Is there a correlation between the improvement in student learning (as measured by the difference in pre- and posttest scores on a chemistry-concepts diagnostic) and shift towards the Assimilative domain in the Kolb Learning Style Inventory?

Null Hypothesis 2

There is not a significant correlation between the improvement in student learning (as measured by the difference in pre- and posttest scores on a chemistry-concepts diagnostic) and shift towards the Assimilative domain in the Kolb Learning Style Inventory.

Alternative Hypothesis 2

There is a significant correlation between the improvement in student learning (as measured by the difference in pre- and posttest scores on a chemistry-concepts diagnostic) and shift towards the Assimilative domain in the Kolb Learning Style Inventory.

Purpose

Adapting the science curriculum to fit within the GPS frameworks is necessary because testing at the state level is aligned with the new standards. The questions on these evaluations are directed toward measuring how well students have applied the concepts they have learned, rather than showing how well students have memorized facts (as was much the instance with the old QCC objectives). The ability of students to do well on these state level tests is a key factor in determining an individual school's adequate yearly progress (AYP), which has ramifications tied to No Child Left Behind (NCLB) mandates.

Since the transition to the GPS curriculum, the scores on state mandated standardized tests (End of Course test [EOCT], Georgia High School Graduation Test – Science Portion [GHSGT – SP] at the Local Area High School [LAHS]) has shown mixed results (see Figure 1). EOCT scores in two science domains (biology and physical science) (Governor's Office of Student Achievement, 2007c) have shown significant increases in the rate of failures experienced by students, although during the 2006-2007 school year the failure rate for physical science dropped slightly from 33% to 29%. Scores on the GHSGT-SP showed a significant drop from a rate of 27% (for two consecutive years) to 17% (Governor's Office of Student Achievement, 2007d). However, this drop can be attributed to change in county policy that prohibits students who have failed to attain certain academic markers from taking the test.

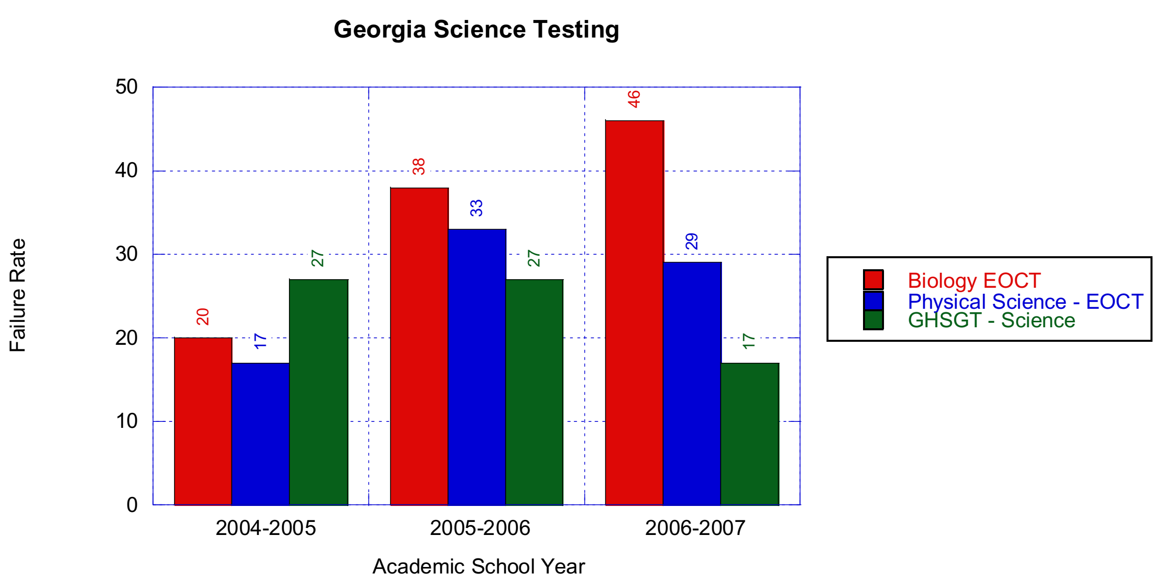


Figure 1. LAHS failure rates on state of Georgia science tests for academic years 2004/2005 –2006/2007.

There is also a disconnect between the effectiveness of the implementation of the GPS as it relates to national tests as well, such as the American College Testing Program – Science Reasoning Portion (ACT – SRP) and the Scholastic Aptitude Test (SAT). Scores on the ACT – SRP at the Local Area High School (LAHS) have been below local, state, and national levels (see Figure 2) (Governor's Office of Student Achievement, 2007a). In addition, although it does not measure direct science aptitude (verbal and math only), the SAT scores have also been well below system levels, while only slightly above national levels (see Figure 3) (Governor's Office of Student Achievement, 2007b).

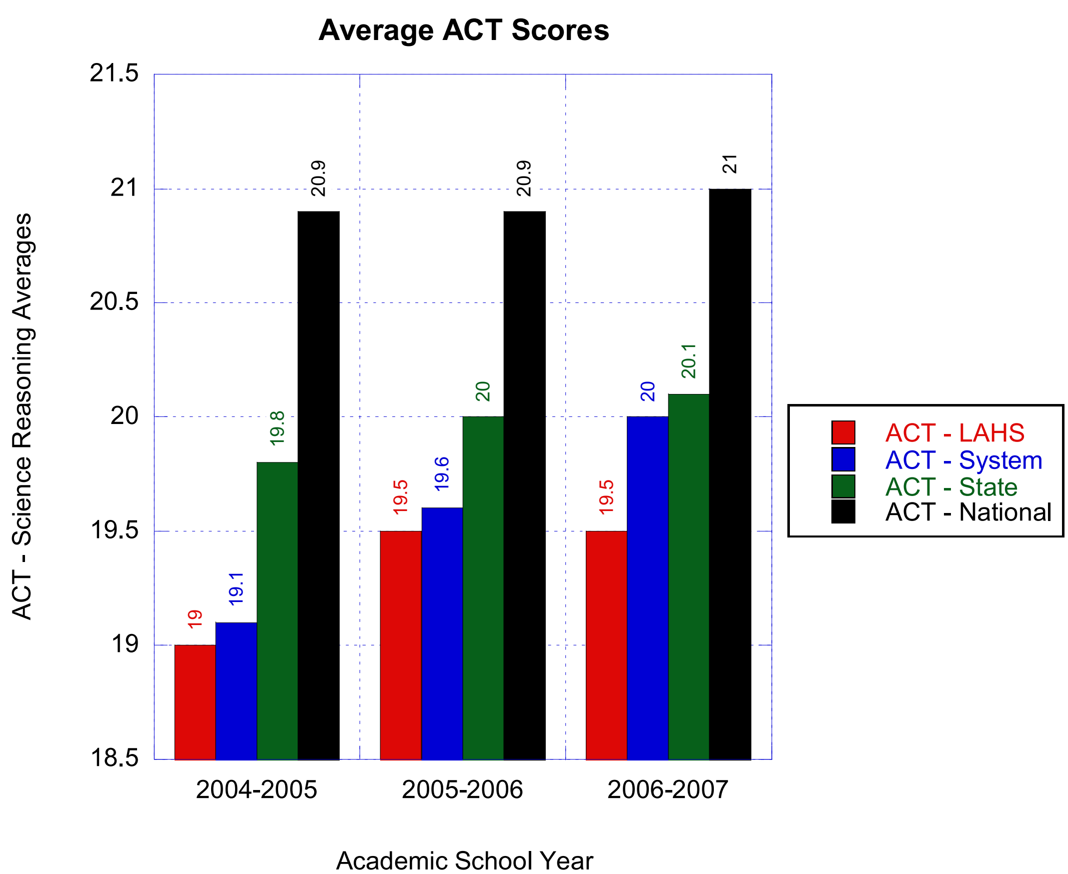


Figure 2. LAHS average ACT (composite and subtest) scores for academic years 2004/2005 - 2006/2007.

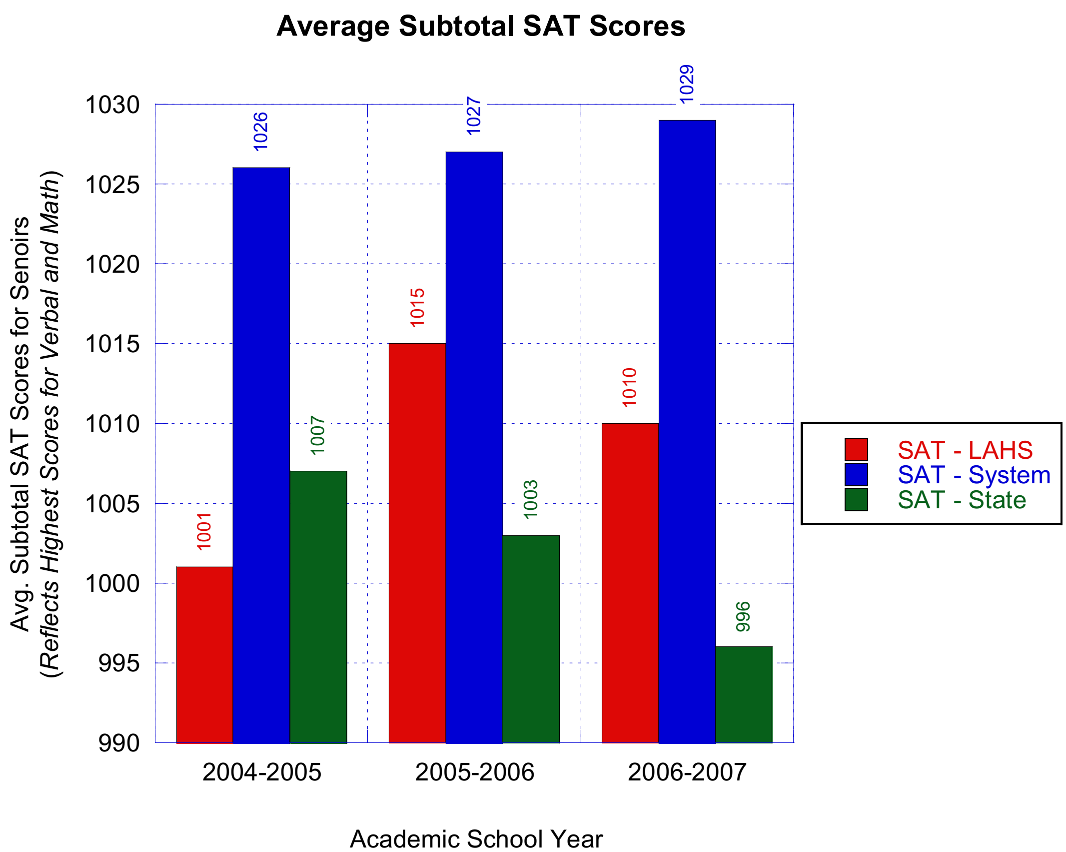


Figure 3. LAHS average (highest scores for verbal and math) subtotal SAT scores for seniors for academic years 2004/2005 - 2006/2007.

The results of the state mandated and national tests give credence to claim that "testing has narrowed curriculum and instruction to focus on test preparation" (Weinbaum et al., 2004, p. 13) rather than concentrating on the application of concepts and the development of scientific habits of mind. Although at the middle school level, further credibility was offered by the actions of the Georgia State School Superintendent, Kathy Cox, when she canceled the scores from the social studies portion of a recent administration of the Criterion-Referenced Competency Test (CRCT) because "there was a disconnect between test questions, what teachers taught, and what the state says students should learn" (Diamond, 2008, p. 1). With this in mind, a logical conclusion can be drawn that increased scores at school, system, and national levels can be achieved through helping students converge and assimilate information.

Theoretical Framework

There is much literature regarding instructional strategies for improving student learning. Many of the suggestions are broad and filled with generalities that offer little or no direct application to upper level concepts driven science classes. Although outside professional development opportunities can help, ultimately the responsibility lies with the teacher to apply strategies and techniques inside the classroom to improve any student's scientific habits of mind.

Little of the literature on improving students' scientific cognitive abilities concerns how to monitor students' progress in transitioning to a standards-based science classroom. Much of the work centers around evaluating pre- and posttest data, yet nothing focuses on the type and style of questions used in these evaluations. In a standards-based science classroom, students should be assisted with increasing their ability to answer higher-level thinking questions (on par with Bloom's taxonomy).

Two items which were employed by this researcher in this endeavor are the (a) Learning Preference Checklist (O'Brien, 1990) and the (b) KLSI (Kolb, 2005). In relation to using the Learning Preference Checklist (O'Brien, 1990) to develop improved cognitive abilities in the field of chemistry, McKeown (2003) writes that "teaching to engage students of different learning styles is a major consideration when developing a science curriculum" (p. 872). Because the human brain processes information based in part on different modes of sensory input (Samples, 2000), improved results can be obtained by addressing the different learning modalities*,* or sensory channels through which a person receives and retains information (McKeown, 2003, p. 872). Moreover, it has been noted that learners can also function in more than one modality, and students with a particular modal strength can supplement their own understanding when material is presented in the alternate forms (McKeown, 2003). According to Tomlinson and Strickland (2005) and Marzano (2005), directing differentiated instruction towards each the three perceived learning modalities gives students the opportunity to demonstrate their mastery of the material presented to them.

The employment of the KLSI as an instrument to measure the cognitive development of chemistry students is corroborated by the main constructs of Kolb's (1984) Experiential Learning Theory (ELT) by which "knowledge results from the combination of grasping and transforming experience" (p. 41). According to Kolb (1984, as stated in de Jesus, Almeida, Teixeira, and Watts 2007), there are two dialectically related modes of grasping and transforming experience. The grasping mode consists of Concrete Experience (CE) and Abstract Conceptualization (AC), while the transforming mode consists of Reflective Observation (RO) and Active Experimentation (AE). Learning styles are "determined by the individual's preferred ways of resolving these dialectics" (de Jesus, 2007, p. 3) (see Figure 4).

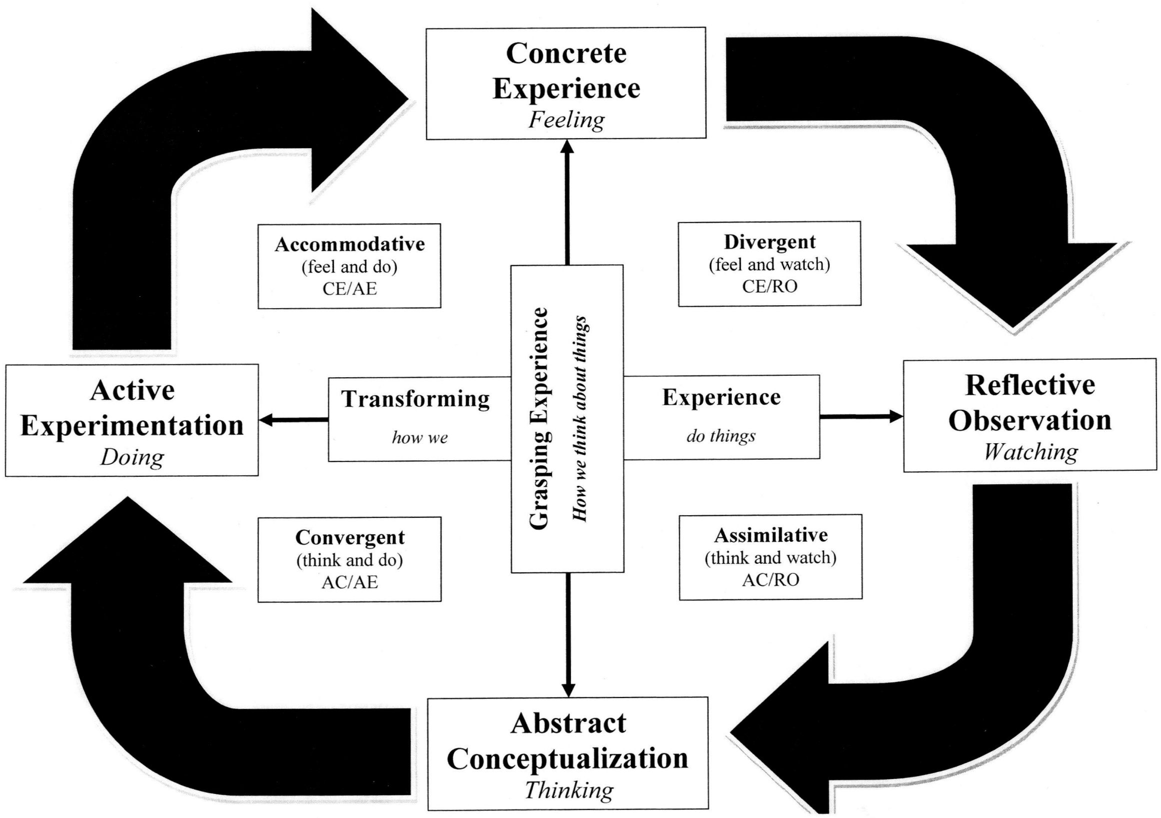


Figure 4. The evolution of learning, relating Kolb's learning situations to learning dimensions (adapted from *Kolb's Learning Styles Diagram* (2006) and (Kolb, 1984, p. 42)).

Kolb's learning styles (2005) include (a) Converger, (b) Accommodator, (c) Diverger, and (d) Assimilator (see Figure 4). Convergers are best at applying what they have learned to new situations; accommodators are kinesthetic in nature and gain insight from practical experience; divergers offer varying and different perspectives, while assimilators can look at a wide range of information and place it into a very concise and logical form (Kolb, 2005; Loo, 2004). According to Felder and Brent (2005), effective instruction for science and engineering students involves teaching around the learning cycle by initially motivating the divergers. Learning is sustained by presenting information and methods to the assimilators, providing practice of the methods to the convergers, and by encouraging applicative explorations by the accommodators. Adaptive flexibility in learning "results from the integration of the dual dialectics of the learning process" (de Jesus et al., 2007, p. 3).

Particular learning dimensions are better suited to a particular type of learning (de Jesus, 2007; Kolb, 1984). Based upon Liam Hudson's (1966) work on undergraduate education [as found in Kolb (1984, p. 86)], the average freshman will have an AE-RO (Active Experimentation – Reflective Observation) value of ≈+3 and an AC-CE (Abstract Conceptualization – Concrete Experience) value of ≈+7 (see Figure 5) according to the KLSI (see Appendix M for author's publication permission). The figures place the learning just within the Assimilative learning domain. Determining the learning dimension of the student will assist in establishing connections which help link their knowledge of the concepts with prior experiences, which in turn will promote their advancement into the critical thinking realm.

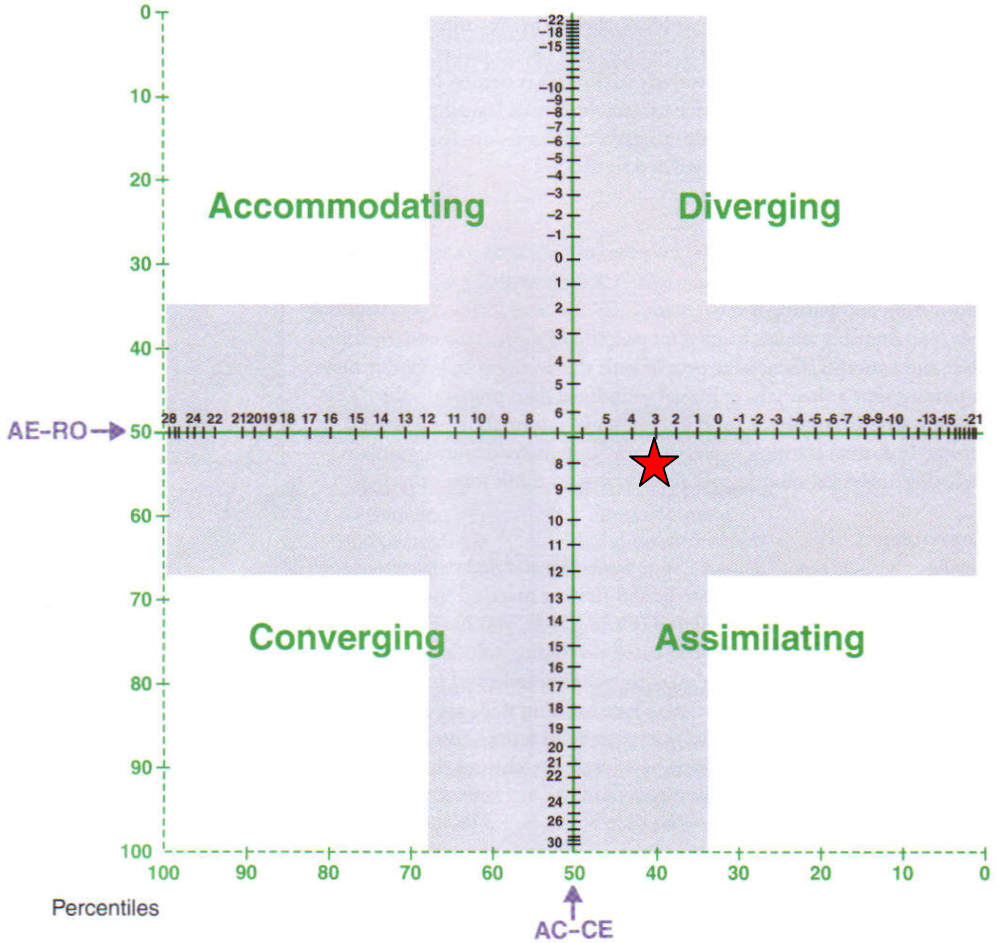


Figure 5. Approximate Assimilative domain proficiency intended ( ) according to the KLSI. Reprinted with permission from the author (Kolb, 2005, p. 7).

Definition of Terms

The following terms were used in the study according to these definitions:

AAAS: An acronym for the American Association for the Advancement of Science. This non-profit organization dedicated towards advancing scientific knowledge and serving society through policy initiatives, programs, and publications (AAAS, 2009).

AC: An acronym for the Abstract Conceptual learning mode in Kolb's Learning Style Inventory (KLSI). An abstract conceptual learning style emphasizes thinking as opposed to feeling. (Kolb, 1984, p. 69).

Accommodator: A learning dimension within Kolb's Experiential Learning Theory which results by the way of transforming and grasping experience. This region is also found in Kolb's Learning Style Inventory and incorporates the individual Active Experimentation (AE) and Concrete Experience (CE) learning styles (Kolb, 1984; Kolb & Kolb, 2005a, Kolb & Kolb, 2005b).

ACT: An acronym for the American College Testing program, which is universally accepted for college admission. Unlike the competing SAT test, the ACT is curriculum-based and included questions which relate to what students have learned in English, Math, and Science high school courses (ACT, 2009).

AE: An acronym for the Active Experimentation learning mode in Kolb's learning Style Inventory (KLSI). An active experimentation learning style emphasizes practical applications as opposed to reflective understanding (Kolb, 1984, p. 69).

Assimilator: A learning dimension within Kolb's Experiential Learning Theory which results by the way of transforming and grasping experience. This region is also found in Kolb's Learning Style Inventory and incorporates the individual Abstract Conceptualization (AC) and Reflective Observation (RO) learning styles (Kolb, 1984; Kolb & Kolb, 2005a, Kolb & Kolb, 2005b; Kolb).

AYP: An acronym for Adequate Yearly Progress. It is an individual state's measure towards the goal of 100% of the students achieving certain standards. It sets the minimum proficiency which school must achieve each year on annual tests and related academic indicators (U.S. Department of Education, 2008a).

Big Idea(s): The building material of understanding which goes beyond discrete facts or skills and focuses on larger concepts, principles, or processes (Wiggins & McTighe, 2005, pp. 328-329).

Bloom's Taxonomy: A hierarchal arrangement of learning objectives (based upon cognitive ability) in which the attainment of higher levels is dependent upon mastering the lower levels. The six individual levels are as follows: 1) Knowledge, 2) comprehension, 3) application, 4) analysis, 5) synthesis, and 6) evaluation (Marzano & Kendall, 2007, pp. 5-8).

CE: An acronym for the Concrete Experience learning mode in David Kolb's Learning Style Inventory (KLSI). A concrete experience learning style emphasizes feeling as opposed to thinking (Kolb, 1984, p. 68).

Converger: A learning dimension within Kolb's Experiential Learning Theory which results by the way of transforming and grasping experience. This region is also found in Kolb's Learning Style Inventory and incorporates the individual Active Experimentation (AE) and Abstract Conceptualization (AC) learning styles (Kolb, 1984, Kolb & Kolb, 2005a, Kolb & Kolb, 2005b).

CRCT: An acronym for the Criterion-Referenced Competency Tests which are given to students in Georgia public schools in grades 1-8. The content of these tests are based on the Georgia Performance Standards (GPS) which describe what students should be able to do in English, Math, Science, and Social Studies (Georgia Department of Education, 2009b).

Differentiated Instruction: As defined by Tomlinson and Strickland (2005, p. 6), this is "A systematic approach to planning curriculum and instruction with goals of honoring each student's learning needs and maximizing each student's learning capacity."

Diverger: A learning dimension within Kolb's Experiential Learning Theory which results by the way of transforming and grasping experience. This region is also found in Kolb's Learning Style Inventory and incorporates the individual Concrete Experience (CE) and Reflective Observation (RO) learning styles (Kolb, 1984, Kolb & Kolb, 2005a, Kolb & Kolb, 2005b).

ELT: An acronym for Experiential Learning Theory which was developed by David Kolb. This theory is reinforced by the idea that knowledge results from the combination of grasping and transforming experience (Kolb, 1984, p. 41).

EOCT: An acronym for a series of End Of Course Tests mandated in 2000 by the A+ Education Reform Act. Each of these tests is aligned with the adopted state curriculum. Each consists of multiple-choice tests questions with four response options. The core high school subjects which are tested are English Language Arts, Mathematics, Social Studies and Science. (Georgia Department of Education, 2009c).

Essential Question: A question that lies at the heart of a subject or curriculum (as opposed to being either trivial or leading), and promotes inquiry and uncoverage (in depth understanding) of a subject. According to Wiggins and McTighe (2005, pp. 342, 352) "Essential questions do not yield a single straightforward answer, but produce different plausible responses."

GHSGT: An acronym for the Georgia High School Graduation Test which is taken by 11th graders in the four core subjects. These tests were designed to measure whether students have mastered essential concepts and skills from the state adopted curriculum (Georgia Department of Education, 2009d).

GOSA: An acronym for the Georgia governor's Office of Student Achievement, formerly known as the Office of Education Accountability. This agency also works closely with several education agencies, including (yet not limited to) the Georgia Department of Education, the University System of Georgia, and the Georgia Professional Standards Commission (Governor's Office of Student Achievement, 2009a)

GPS: An acronym for the objective-based curriculum known as the Georgia Performance Standards which was implemented in 2002 in order to develop a student's problem solving abilities (Georgia Department of Education, 2007).

HOPE: An acronym for the scholarship program known as Helping Outstanding Pupils Educationally. This program was created by then Georgia Governor Zell Miller in 1993 and is completely funded by Georgia Lottery proceeds. Any resident, who graduates from a Georgia high school with a 3.0 average (on a 4.0 scale), and attends a Georgia public college or technical school, will be awarded full tuition, a textbook allowance, and student fee reimbursement. The renewal of the scholarship is dependent upon maintaining a 3.0 grade point average and achieving satisfactory academic progress (Technical College System of Georgia, 2009).

Ipsative scoring: In relation to Kolb's Learning Style Inventory (KLSI) – A possible error which results when respondents are required to rank order information (Kolb, 1984, pp. 67-68). This scoring can lead to negative correlations to be drawn from measured attributes.

KLSI: An acronym for the Kolb Learning Style Inventory developed by David Kolb (2005) to explain the cyclical maturation of the learning process. This instrument can also determine the learning dimension of the individual student and assist in establishing connections which help link conceptual knowledge with prior experiences.

LAHS: An acronym for the local area high school where the research study in question took place.

LCSS: An acronym for the local county school system where the research study in question took place.

Modality: A sensory channel through which a person receives and retains information (McKeown, 2003, p. 872).

NSES: An acronym for the National Science Education Standards. These standards were developed to guide school-aged children in the United States to become more scientifically literate (National Science Education Standards, 1998, p. 1; National Academies Press, 2009a, p. 1).

NCLB: An acronym for No Child Left Behind. The main federal law enacted in 2001 affecting education of students from kindergarten through high school. This law is based on four principles: 1) accountability for results, 2) more choices for parents, 3) greater local control and flexibility, and 4) an emphasis on doing what works based on scientific research (U.S. Department of Education, 2008b)

Paradigm Shift: A fundamental change in approach.

Perry Model: A student intellectual development model showing comparisons to Kolb's Experiential Learning Theory (ELT), by which students are evaluated as they progress in their academic major. Of the nine stages, the first five refer to development within a specific academic discipline while the other four refer to individual identity development (Zielinksi & Schwenz, 2004, p. 114).

POGIL: An acronym for process-oriented-guided-inquiry-learning. In this particular mode of inquiry learning, students work in small groups on instructional modules that present them with information and data, followed by leading questions (generated by the instructor and based upon need) which guide them towards the formulation of their own conclusions (Prince & Felder, 2006, p. 9).

Project 2061: A long term science reform initiative undertaken by the American Association for the Advancement of Science (AAAS) in 1985 to assist school aged children with literacy problems concerning science, technology, and math (STEM) (Advancing Science Serving Society, 2009; Benchmarks for Science Literacy, 1993; Benchmarks On-line, 2009; Johnson, 1989, pp. 8-9).

Regents Exam(s): A group of tests in the core high school subjects designed by the New York State Department of Education which are required in order to receive a Regents diploma. (The Princeton Review, 2003, p. 3).

RO: An acronym for the Reflective Observation learning mode in Kolb's learning Style Inventory (KLSI). A reflective observation learning style emphasizes understanding as opposed to practical application. (Kolb, 1984, p. 68).

SAT: An acronym for the Scholastic Aptitude Test, which is a standardized test used for college admissions. Now referred to as the SAT Reasoning Test, this evaluative devices tests student's knowledge in Reading, Writing, and Mathematics (CollegeBoard, 2009).

Scaffolding: An instructional technique which provides support for students enabling them to participate in classroom activities and instruction. Scaffolds can take on many forms, including, yet not limited to, supplemental materials, highlighted text, and graphic organizers. (Tomlinson & Strickland, 2005, p. 30).

Scientific Inquiry: The evidence-based process that scientists engage in to study and propose explanations about aspects of the natural world. When applied to the classroom environment, this mode of learning is indicative of student involvement in activities and processes which promote understanding scientific concepts and principles (Trout et al., 2008, p. 30).

Scope and Sequence: The proper breadth and arrangement of work designed to address the course content and standards (Wiggins & McTighe, 2005, pp. 294-295).

STEM: An acronym for Science, Technology, and Math education modules.

VAK: An acronym for student modal preference in the Visual, Auditory, and Kinesthetic domain. Lynn O'Brien's (1990) Learning Preference Checklist will classify students into these categories based upon calculated percentages.

VARK: An acronym for student modal preference in the Visual, Auditory, Read/Write, and Kinesthetic domain. The change, as compared to Lynn O'Brien's VAK, was made by Neil Fleming in 1987, when he split the Visual (V) dimension into two parts: 1) V – represents the symbolic (traditional) portion and 2) R – represents the in-text portion (also known as reading/writing) (Fleming, 2009).

QCC: An acronym for an objective-based curriculum known as the Quality Core Curriculum which was replaced in Georgia in 2004 with the Georgia Performance Standards (GPS) (Georgia Department of Education, 2007).

Assumptions, Limitations, Scope and Delimitations

The researcher conducted this study using the following assumptions, limitations, and scope and delimitations.

Assumptions

In this study, it is assumed that the students enrolled in chemistry were representative of all students taking chemistry at the LAHS during the course of the study. It is also assumed that the students in the course have successfully completed the prerequisite math and science courses and thus all students will begin instruction at the same cognitive level. The researcher will also assume that the ability of the teacher to adapt and differentiate the curriculum is more than adequate to address all learning modalities in a manner to attain the intended results. In addition, the researcher assumes that all diagnostics will be taken seriously and will accurately reflect the level of conceptual development attained.

Limitations

This study acknowledges several limitations. First, it was conducted in a single geographical area with a randomized convenience sampling of students being limited to one instructor at one high school. Because of this, the results may not be transferable to other instructors within the LAHS or the Local County School System (LCSS). In addition, because the study was conducted during the course of one fall semester, it may not be possible to generalize the results to other populations taught during other semesters.

Scope and Delimitations

It is common knowledge that an individual's attitude towards a particular subject matter or instructor can greatly affect his or her learning. If students take vested interest and remain actively and authentically engaged, learning will ensue. In order to attain the desired results, the researcher had to work within the boundaries of the local, county, and state GPS curriculum mandates. In addition, due to time constraints of block scheduling and planned standardized testing schedules, the instructor kept a certain pace in order to teach all required components of the curriculum.

Professional Application and Social Significance

Professional Application

While there are many models and educational surveys that offer suggestions on how to address the developmental progression of students, two show greater promise in specifically addressing the needs of the science student: (a) The Learning Preference Checklist (O'Brien, 1990) which classifies student learning preference in three *modalities* – visual, auditory, and kinesthetic (VAK), and the (b) Kolb Learning Style Inventory (KLSI) (Kolb, 2005) which explains the cyclical maturation of the learning process.

The VAK model was utilized to assist in incorporating differential learning techniques into classroom instruction and activities. The KLSI determined the learning dimension of the student and assisted in establishing connections which help link knowledge of the concepts with prior experiences. When both models are used in conjunction with one another, students will promote their advancement into the critical thinking realm, which is the region where standards-based test questions are concentrated.

Social Significance

If the format and results of this research study do prove successful, a reasonable assertion can be made that learning styles do characterize an individual's ability to process information. Even when being held accountable for the standards, "it is possible for [students] to learn in varied, yet appropriate and meaningful ways" (Ferrier, 2007, p. 22). Helping students converge and assimilate information builds skills they can use in many situations. If applied across interdisciplinary tracts at the high school level, students could benefit in the short term with increased standardized test scores and have increased chances in retaining Georgia's HOPE (Helping Outstanding Pupils Educationally) scholarship at the college level. Individual schools could also benefit directly through the continued renewal of adequate yearly progress, which indirectly has ramifications tied to teacher morale and retention rates. Long term benefits of using learning styles with the associated use of the KLSI as a training tool can also lead to individuals choosing a career path that matches their ability to process the information.

Summary

There has been a large amount of literature published regarding instructional strategies in order to improve student learning in the classroom setting. Yet, many of the suggestions provided are broad and filled with generalities that offer little or no direct application to an upper level concepts-driven class such as chemistry. The main impediment in addressing learning in chemistry is that it is considerably limited in the way in which information can be conveyed. There are best instructional practices in which the approach cannot be deviated from due to inviolate scientific laws and principles. The way chemistry has to be approached may not be within the student's preferred learning parameters. Although differentiated instructional techniques have associated benefits, the focus should not lie entirely within this area. The principal focus should lie in monitoring the developmental progression of the individual student as they transition through chemistry (or other science courses) rather than waiting for scores on a state-mandated test at the end of the semester or school year.

Transition

Section 2 of this quantitative study on *Assimilative Domain Proficiency and Performance in Chemistry Coursework* includes a review of the literature addressing the problem and related issues. An association with prior research is also established. Section 3 explains and justifies the research methodology. The study design, approach, setting, and sampling size are described and defended. There is also a detailed description of the instrumentation and materials utilized and how the data was analyzed.

Section 4 concerns the results of the study. A thorough data analysis is given and the results of the study are communicated and interpreted in relation to the problem. Section 5 describes the projects' strengths and limitations in addressing the problem. An analysis of what was learned is included along with possible applications and directions for future research relating to the study topic.

CHAPTER 2:

LITERATURE REVIEW

Introduction

The review of the literature initially focused on evidentiary findings to substantiate the position that students, either entering or currently enrolled at the LAHS, need assistance in converging and assimilating scientific knowledge and concepts. Based upon these findings, a discussion of the foundations of David Kolb's Experiential Learning Theory (ELT) is presented along with its implications for use in modifying the chemistry curriculum content at the LAHS to develop a student's cognitive abilities. An extension to Bloom's Taxonomy and the Perry Model is also presented. In addition, the Georgia GPS curricular frameworks are discussed along with unifying themes, including the relationship between learning styles and differentiated instruction, understanding by design, and scientific inquiry. The basis for the use of the KLSI will also be presented along with its use in associated studies.

The strategy utilized to research the aforementioned topics focused on using education-related databases including EBSCO Host, ProQuest, SAGE, ERIC, and Google™ Scholar in addition to traditional methodologies. Multiple dissertations and theses were also reviewed on topics that centered on chemistry curriculum standards and other associated curricular concerns with extensions to Kolb's ELT and his Learning Style Inventory (KLSI). Individual topics also included differentiation and learning styles. Local, state, and national statistics centering around standardized testing data was found through the GOSA website.

Evidentiary Findings

Due to No Child Left Behind (NCLB) mandates, curricular focus has been narrowed so teachers can better prepare students for specific state mandated tests in order to have increased chances of achieving adequate yearly progress (AYP) (Weinbaum et al., 2004). In many instances, instruction in certain subject areas gets suspended in favor of specific AYP test review weeks prior to testing. The main focus is placed on reading and math, while other content areas (i.e., science) takes a less favorable position. Currently elementary and middle school students in Georgia are required to take the Criterion-Referenced Competency Tests (CRCT) in reading, English, math, science, and social studies (dependent upon grade level). However, they are only required to pass the basic literacy subjects in order to get promoted to the next grade. Currently, third graders must pass only the reading examination for promotion, while students in the fifth and eighth grades must only pass the reading and math portions for promotion (Atlanta *Journal Constitution*, 2009a-c).

Despite the aforementioned requirements for promotion (especially from the eighth grade), a recent Atlanta *Journal Constitution* (2009d) article points out that many Georgia middle school students that failed to meet the minimum requirements, and were socially promoted. Data collected (after a summer remediation session) showed that a large percentage of eighth graders within the Local County School System (LCSS) which feed into the Local Area High School (LAHS) had undergone the same fate with the reading and math portions of the CRCT. Figure 6 shows the number of students tested at each of the three feeder middle schools and how many did not pass the spring administration of the CRCT and the associated summer remediation test for the 2007-2008 school year (Atlanta *Journal Constitution*, 2009a-c).

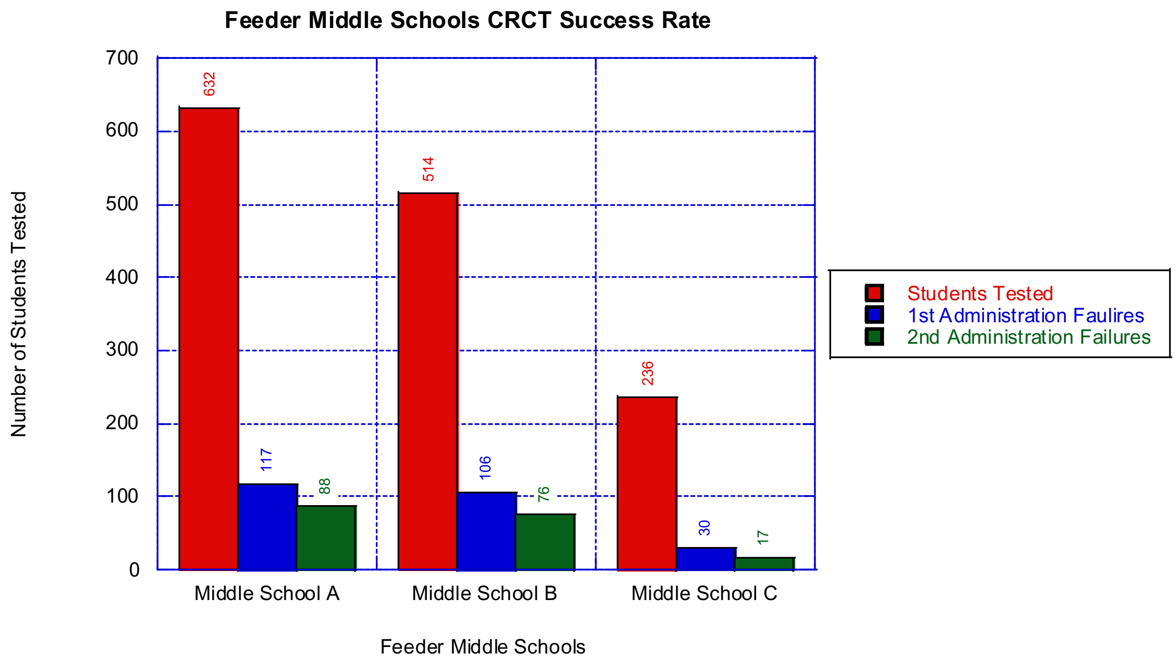


Figure 6. Feeder middle school failure rates on the CRCT for academic school year 2007-2008.

Figure 7 displays the percentages of students in each of the three feeder middle schools who were promoted, despite failing two administrations of the state mandated CRCT. The percentage retention for each of the three feeder middle schools were 92.05 %, 96.05 %, and 94.12 % respectively (Atlanta *Journal Constitution*, 2009a-c).

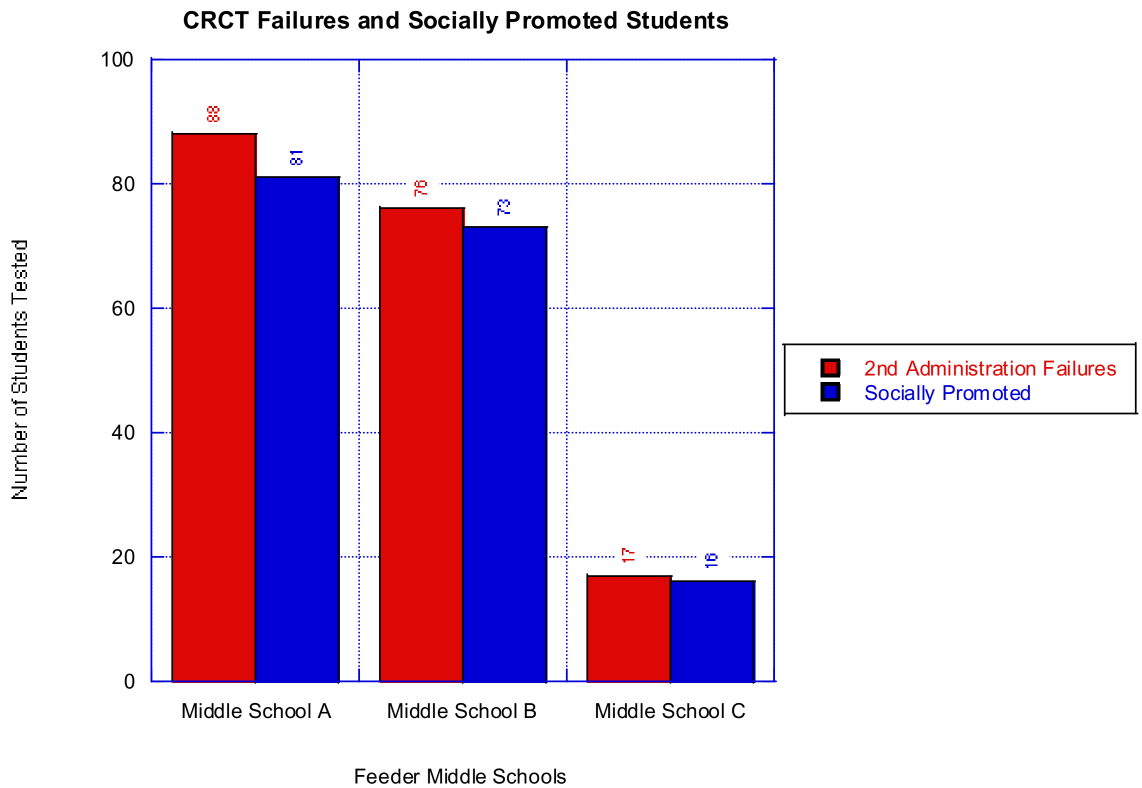


Figure 7. Feeder middle school CRCT failures versus socially promoted students for academic school year 2007-2008.

With priority given to reading and math in the primary and middle grades for AYP purposes, academic progress in other subject areas, including science, many times is ignored or overlooked by the administration. Continuing data from the 2007-2008 administration of the CRCT from the three feeder middle schools shows that the failure percentage for science is quite high, with each school averaging a rate around 25 % each (see Figure 8) (Atlanta *Journal Constitution*, 2009a-c). A weighted average shows that 354 of 1382 (weighted percent = 25.8 %) students tested, failed to obtain a basic understanding of scientific concepts and processes.

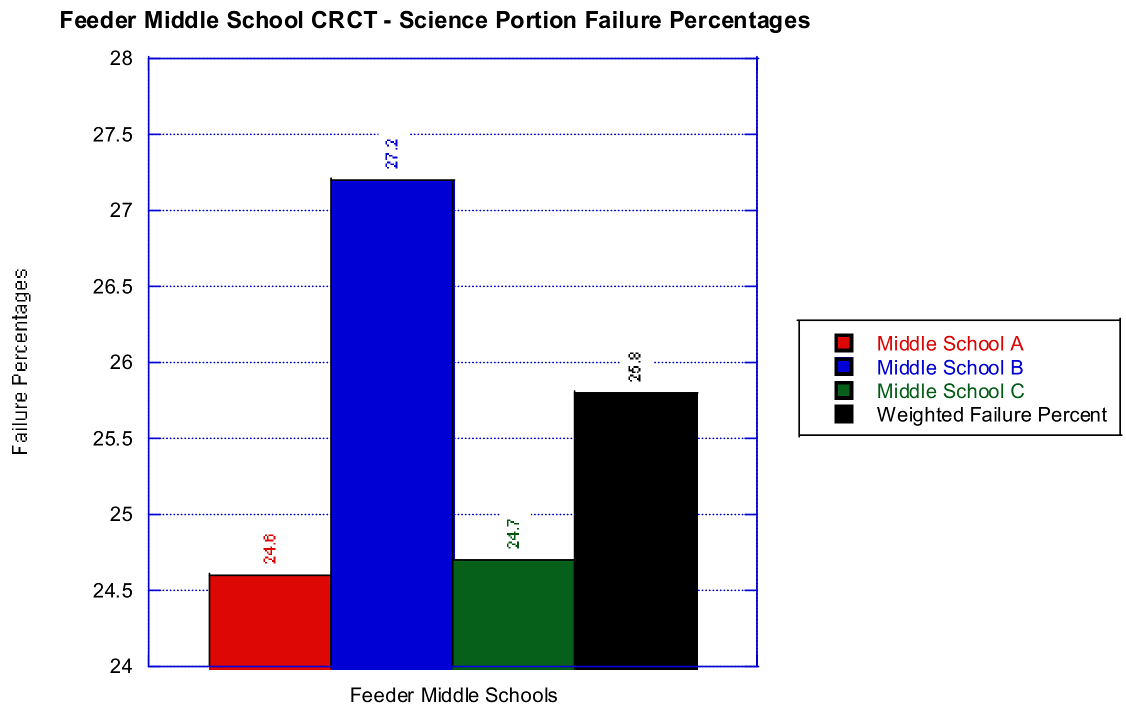


Figure 8. Feeder middle school failure rates on the CRCT – Science Portion for academic school year 2007-2008.

With the drift towards social promotion in the middle schools within the LCSS and the reported trend in grade inflation amongst high school classes with an EOCT component in the state of Georgia (Vogell, 2009a, 2009b), there is ample evidence to corroborate the position that much needs to be done to assist students in converging and assimilating information. Doing so "may impact student's college success, HOPE scholarship retention rates, and the need for remedial support in college" (GOSA, 2009f, p. 1).

In this era of data-driven decision making, there is more than sufficient proof to substantiate the position that students at the LAHS need assistance in attaining knowledge of the principles and concepts on which science is based. Without knowledge of the concepts, problem solving becomes a mathematical exercise, while some concepts explain how circumstances change. There also has to be a noted increased ability to solve problems, because in the real world it does not necessarily matter what you know, but how you apply the information which you have learned. The process of which differs with subject content.

There has been a large amount of literature published regarding instructional strategies in order to improve student learning in the classroom setting. Yet, many of the suggestions provided are broad and filled with generalities that offer little or no direct application to an upper level concepts-driven class such as chemistry. The main impediment in addressing learning in chemistry is that it is considerably limited in the way in which information can be conveyed. There are best instructional practices from which teachers cannot deviate. For example, only a few strategies can be utilized to form and balance chemical equations. The way chemistry has to be approached may not be within the student's preferred learning parameters. Although differentiated instructional techniques have associated benefits, the focus should not lie entirely within this area. The principal focus should lie in monitoring the developmental progression of the individual student as they transition through chemistry (or other science courses) rather than waiting for scores on a state-mandated test at the end of the semester or school year. The basis for this measure lies in effectively utilizing the KLSI, where the underlying foundations are based upon Kolb's ELT.

The Experiential Learning Theory

The essence of utilizing an experiential pedagogy in developing an adaptive chemistry curriculum is that (if utilized effectively) it can permit higher levels of cognitive development (Peterson, 2007), the suppositions of which are part of the foundational constructs of David Kolb's Experiential Learning Theory (ELT). This theory itself draws on the work of many prominent constructivist scholars, including John Dewey and Jean Piaget, who believed personal experience was essential to developing cognitive understanding. The ELT is built upon six propositions which are shared by these scholars (Brennan, 2005; Kolb & Kolb, 2005, p. 2):

1. Learning is a process and should not solely be evaluated as to how well an individual covers a given series of objectives. Rather learning should be based on standards which relates to the level at which one effectively applies information which has been learned. To enhance the process of learning, students should be actively engaged in a process which best accentuates their preferred learning modality.
2. All learning is relearning. The relationships and experiences developed by all individuals can be summarily transferred and applied to many other learning situations as long as the body of knowledge or relationship is already consistent with what the individual in question believes to be true.

3. The process of experiential learning revolves around resolving dialectics within opposing regions of the cerebral cortex of the brain – from modes of watching and doing and feeling and thinking. According to Zull (2002), concrete experiences (CE - feeling) come through the sensory cortex while reflective observation (RO - watching) involves the integrative cortex at the back of the brain. Abstract conceptualization (AC - thinking) occurs in the frontal integrative cortex and active experimentation (AE - doing), involves the motor brain (see Figures 4 and 9).

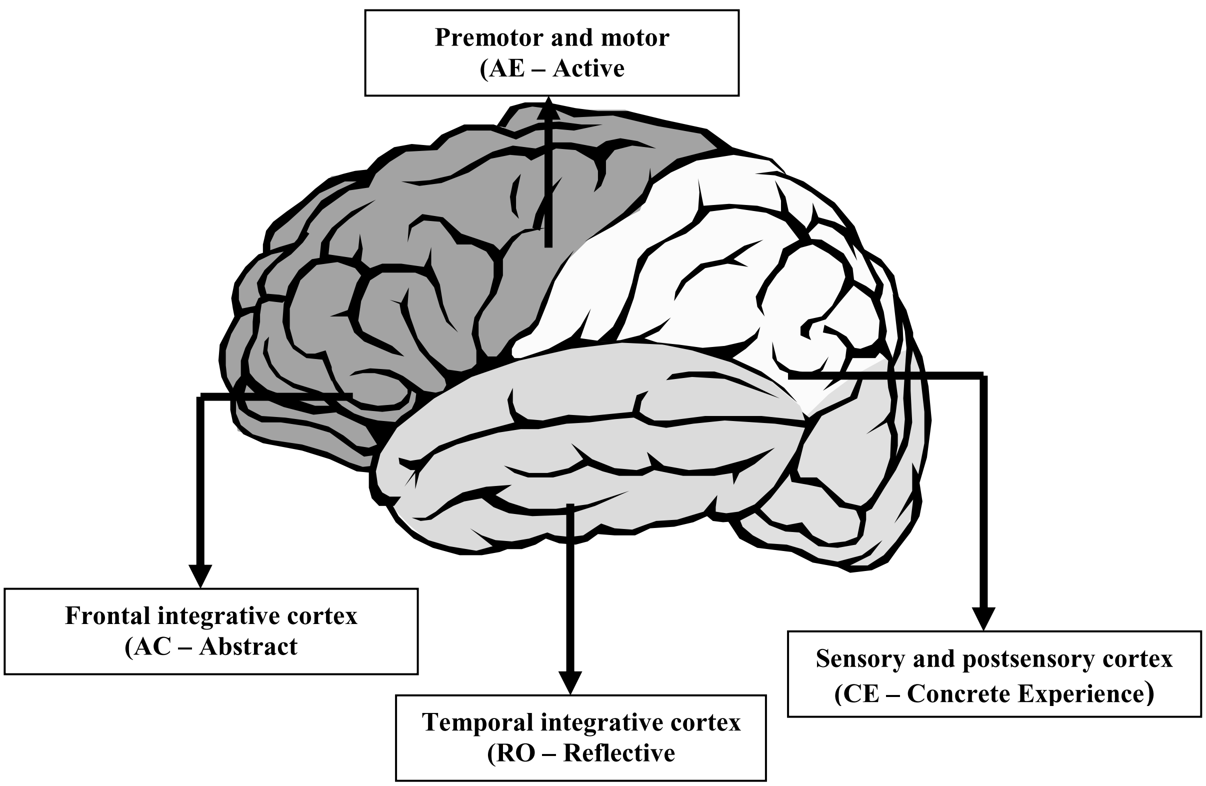


Figure 9. Regions of the cerebral cortex associated with experiential learning including correlations to David Kolb's ELT (adapted from Kolb & Kolb, 2005a, p. 4 and Zull, 2002, p. 35).

4. Learning should be thought of and approached as an integrated process relating to how an individual thinks, feels, perceives, and behaves in accordance to real-world situations.
5. Learning occurs when the dialectic process within the brain is resolved and new experiences can be assimilated into existing concepts to create a new body of knowledge.
6. Learning is the process of creating and reconstructing the personal knowledge of the individual learner based on their experiences. This stands in sharp contrast where preexisting, or fixed ideas, are transmitted directly to the learner, which is a common current educational practice.

The foundational constructs of Kolb's ELT hold true that "knowledge results from the combination of grasping and transforming experience" (Kolb, 1984, p. 41). According to Mainemelis et al. (2002, as found in de Jesus et al., 2007), the ELT is characterized by two modes of grasping experience (Concrete Experience (CE) and Abstract Conceptual (AC)) and two modes of transforming experience (Reflective Observation (RO) and Active Experimentation (AE)). Crossing the two dialectically opposed modes leads to four learning styles with specific characteristics – Diverging, Converging, Assimilating, and Accommodating (see Figure 4) (Brennan, 2005; de Jesus *et al*., 2007; Kolb, 2005; Kolb, 1984; Kolb & Kolb, 2005). The ELT integrates these learning modes/styles into a learning cycle (or spiral) to create "learning tension" (de Jesus et al., 2007, p. 3) by which the learner "touches all bases – experiencing, reflecting, thinking, and acting in a recursive process that is responsive to the learning situation and what is being learned" (see Figure 4) (Kolb & Kolb, 2005).

When teaching around the cycle or spiral, "students are taught partly in a manner which they prefer" and "partly in a less preferred manner" (Prince & Felder, 2006, p. 7). The prior method focuses students' attention and provides an increased level of comfort which can instill a certain level of self-confidence (Peterson, 2007, p. 288; Prince & Felder, 2006, p. 7). The latter "provides practice and feedback in ways of thinking that [students'] might be inclined to avoid, but will have to use [to function as effective professionals]" (Prince & Felder, 2006, p. 7).

According to Prince and Felder (2006, p. 7) and Armstrong and Parsa-Parsi (2005, pp. 682-684), teaching around the cycle involves asking four questions of student's at various points. The four focal questions (*Why*? *What*? *How*? *What If*?) have implications for designing educational programs and should be infused into the curriculum. The rationalization of these items is as follows, while Figure 10 (combined with the infusion of Figure 4) shows the application of the curricular framework:

Why? The instructor introduces a problem and provides motivation to solve the problem by relating to the student's interests and prior experiences.

What? The instructor must provide opportunities for students to reflect on observations by presenting and utilizing relevant facts, principles, theories, and problem-solving strategies.

How? Guided hands-on practice is essential so that students can learn to approach problem-solving from the correct perspective (course dependent).

What if? Instructors must provide and encourage further exploration of learned material while students must be prepared to apply this material to new situations.

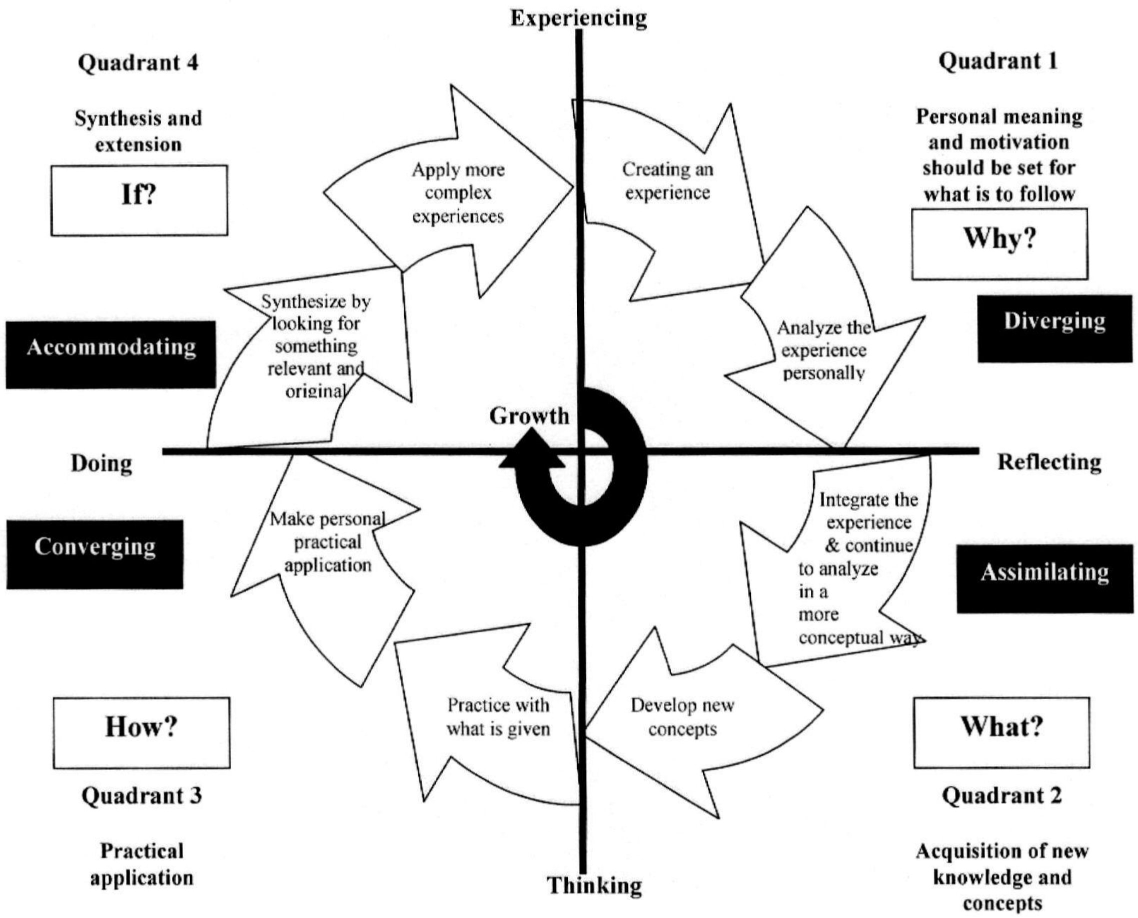


Figure 10. Curricular (cyclical) framework including focal questions and explanations, along with David Kolb's learning dimensions (adapted from Armstrong & Parsa-Parsi, 2005, p. 683).

Learning Dimensions and Styles

The incorporation of learning styles (i.e., Accommodator, Assimilator, Converger, and Diverger) into Kolb's Experiential Learning Theory, has lead into the identification of four different learning dimensions: 1) Abstract Conceptualization (AC), 2) Active Experimentation (AE), 3) Concrete Experience (CE) and 4) Reflective Observation (RO). Each of these identified dimensions combined with learning styles "identifies the strengths and weaknesses of a learner" (Bastable, 2005, p. 92).

The *accommodator* incorporates the AE and CE learning styles. Individuals within this dimension are adaptive to educational situations. They are shown to be intuitive rather than logical when it comes to processing information, which can leave one without a true understanding of why particular choices have been made (Bastable, 2005, p. 94; Gregory & Hammerman, 2008, p. 31; MacKeracher, 2004, p. 86). These learners perform better in careers which are "action-oriented" such as marketing and sales (Kolb & Kolb, 2005a, p. 197). Undergraduate business/management and education majors also fall into this category (Kolb, 2005, p. 15; Kolb, 1984, p. 85).

The *assimilator* incorporates the AC and RO learning styles. Individuals within this learning dimension are sometimes indifferent to individuals and are generally more focused on applying abstract concepts (Bastable, 2005, p. 94; Kolb & Kolb, 2005a, p. 136). In addition, this type of learner works well as a goal setter and systematic planner (Gregory & Hammerman, 2008, p. 31). These individuals reflect on how newly learned information is processed and how it is related to their past experiences. Learners which are assimilative in nature are also more inductive than deductive in their approach to education (which differs from traditional approaches) (Bastable, 2005, p. 93). Undergraduate mathematics, economics, sociology, and chemistry majors also fall within this category (Kolb, 2005, p. 15; Kolb, 1984, p. 85). These individuals also thrive professionally in specialist and technology careers (Kolb & Kolb, 2005a, p. 197).

The *converger* incorporates the AC and AE learning styles. People with this learning style are more deductive in their approach to learning (Gregory & Hammerman, 2008, p. 31) and have the ability to find practical applications for their ideas and theories (Bastable, 2005, p. 93) as compared to dealing with social and interpersonal issues (Kolb & Kolb, 2005a, p. 197). A potential weakness of individuals which lie in this learning dimension is that many times there is a rush to judgment when making decisions because of the belief that time is of the essence (MacKeracher, 2004, p. 86). Professionally engineers (on the average) fall into this dimension (Kolb, 1984, p. 85). Probable undergraduate majors could also include those in the computer science, medical, and environmental science fields (Kolb, 2005, p. 15).

The *diverger* incorporates the CE and RO learning styles. Typically an individual which is categorized as a diverger is a "people person" (Gregory and Hammerman, 2008, p. 31) and learns the best in situations where they are participating in cooperative group activities or brainstorming sessions. Collectively, these individuals are imaginative, emotional, and are sensitive to other's views (Bastable, 2005, pp. 92-93; Kolb & Kolb, 2005a, p. 196). A potential weakness of divergent learners is that they can become engrossed in possible alternative explanations and might not be able to narrow down choices for further discussion or exploration (MacKeracher, 2004, p. 85-86). Possible professional careers include work in the social services, including social work, psychology, and public policy (Kolb, 2005, p. 15). Additional undergraduate majors could also include English and History (Kolb, 1984, p. 86).

Implications for Developmentally Appropriate Practices

According to Ghaoui (2003, p. 223), “Learning is a complex process that differs from individual to individual”. With the incorporation of Kolb’s *Experiential Learning Theory* to evaluate instruments such as the *Learning Style Inventory*, there are implications for constructing developmentally appropriate practices within the realm of chemistry.

According to Zielinski and Schwenz (2004, pp. 109-110), there are three main goals which instructors should have when developing a physical chemistry course. First, the instructors must convey the subject’s main concepts and enduring understandings, while being cognizant of time-constraint factors. Secondly, instructors must foster the growth of essential skills while making student’s understand the significance of their use. Thirdly, instructor’s must further develop critical thinking skills while relating how these skills specifically relate to developing more abstract knowledge of a chemical nature.

Zielinksi and Schwenz (2004, p. 114) continue to mention that “learning becomes a fitting of new data into old frameworks.” This is difficult for learning in a chemical forum because knowledge construction of this design is best facilitated by having the instructor adjusting their schema. Although there are several intellectual models which involve teaching and learning, the *Perry Model* draws comparisons to Kolb’s ELT because of the formulation of stages of development. Of the nine stages in this model, which specifically addresses academic career measurement, the first five are interdisciplinary (subject specific) while the latter four are important for identity development. Attributes included in this branch are: 1) Received knowledge, 2) subjective knowledge, 3) procedural knowledge, and 4) constructed knowledge. These ideas can most assuredly be extended to expanding one's chemical knowledge and even draw comparisons to Bloom's Taxonomy.

Bloom's Taxonomy and the Perry Model

A review of Bloom's Taxonomy by Marzano and Kendall (2007, pp. 5-8) shows that there are six levels of cognitive processes, each possessing certain definable characteristics. The levels are as follows: 1) Knowledge, 2) comprehension, 3) application, 4) analysis, 5) synthesis, and 6) evaluation. When comparing Bloom's attributes to those of the Perry Model, received knowledge (Perry attribute 1) shows parallels to knowledge (Bloom's level 1) and comprehension (Bloom's level 2), in the fact that questioning requires basic information recall along with an understanding of concepts and key terms (Crowe, Dirks, & Wenderoth, 2008, p. 369). Subjective knowledge (Perry attribute 2) shows a correlation to application (Bloom's level 3) by which questioning requires the comprehension of an abstraction in which the student will make a prediction regarding the most likely outcome (Crowe *et al*., 2008, p. 369; Marzano & Kendall, 2007, pp. 6-7). Procedural knowledge (Perry attribute 3) is linked to analysis (Bloom's level 4) by "emphasizing the detection of relationships of the parts and of the way they are organized" (Marzano & Kendall, 2007, p. 7). This is followed by (in the highest hierarchal context) by constructed knowledge

(Perry attribute 4). This level shows a synthesis of Bloom's levels 5 and 6 (synthesis and evaluation). Here student's weigh the importance of possible solutions to a problem and present information pertinent only to the argument itself rather than constructing a novel response (Crowe *et al*., 2008, p. 369; Marzano & Kendall, 2007, pp. 7-8).

Based on these attributes, intended undergraduate science majors rate on the first stage of identity development in the Perry Model (received knowledge). After four years of college, chemistry (specific) majors rate, at best, on the third stage (procedural knowledge). As a consequence, many students are not fully developing the cognitive processes to foster continued growth in the field. An additive objective when considering curriculum design (specifically chemistry) is to "[develop] a student's ability to ask substantive questions" (Zielinski & Schwenz, 2004, p. 114). This begins in earnest with inquiry learning as noted in Lee (2004) and Prince & Felder (2006). Comparisons regarding these stages of development can be extrapolated to fit students within the high school chemistry classroom as well.

Such a transformation would necessitate a paradigm shift "away from content and toward intellectual abilities through the application of the elements of reasoning, an understanding of the traits of the reasoning mind, and maintenance of standards for reasoning" (Zielinski & Schwenz, 2004, p. 114). Zielinski and Schwenz (2004) further elaborate that this is why chemistry is such a difficult class for many - In essence students are being asked to do what they are not prepared for. Thus, there must be a "refocusing" of the curriculum (from teacher-centered to student-centered) so students can develop the requisite reasoning skills in conjunction with chemistry concepts.

GPS Aligned Chemistry Curricular Frameworks

It is clear that the curricular frameworks are what drive instruction in physical chemistry and differentiated instruction, and other associated methodologies, offers the foundation needed to develop commensurate scientific habits of mind. In analogous terms, the frameworks are representative of a train, and the method of instruction and or delivery exemplifies the tracks. The train (frameworks) provides the momentum which drives instruction and necessitates learning. The tracks themselves provide a direction and a support mechanism to help the train arrive at its final destination on-time (or perhaps ahead of schedule).

Georgia GPS Chemistry Curriculum

The Georgia Performance Standards in chemistry are based upon two components. The first of which is based upon Project 2061's *Benchmarks for Science Literacy* (1993), which provide "educators with sequences of specific learning goals" which can be used to help design and support a particular (science) subject curriculum (Advancing Science Serving Society, 2009, p. 1). When drafting Georgia's chemistry content standards, the second (and supporting) component relied heavily upon was the National Research Council's *National Science Education Standards* (Advancing Science Serving Society, 2009; Georgia Department of Education, 2009a) which were "designed to guide [the United States] toward[s] a scientifically literate society" (National Science Education Standards, 1998, p. 11; National Academies Press, 2009a, p. 1)

Project 2061. Project 2061 is a long-term science reform initiative originally undertaken by the American Association for the Advancement of Science (AAAS) in 1985. The namesake for this ambitious undertaking coincided with the initial appearance of Halley's Comet in 1985 and its eventual return in 2061. The motivation for this venture was a concern that many American school-children were considerably deficient in education modules revolving around Science, Technology, and Math (STEM). Due to the enduring nature of the project, it was initially organized into three implementation phases (Johnson, 1989, pp. 8-9):

Phase I established a conceptual base by defining the knowledge, skills, and abilities student's should acquire (at various stages) as they progress through school, from kindergarten through twelfth grade. Phase II produced a variety of alternative curricular models to be used by local and state school districts to model how the infusion of curricular benchmarks can be successful for students. The movement of many states towards a performance-based curriculum represents the culmination of Phase III (Johnson, 1989, pp. 8-9).

It is important to point out that Project 2061 does not advocate for any particular curriculum design, yet it does encourage individual teachers to differentiate curricular aspects to allow students to experience science in such a manner which accentuates their strongest attributes (Advancing Science Serving Society, 2009; Benchmarks for science literacy, 1993; Benchmarks On-line, 2009)., In all, Project 2061 (as taken from Advancing Science Serving Society, 2009):

- Describes the levels of understanding and ability that all students are expected to reach on the way to becoming science literate;
- Concentrates on the common core of learning that contributes to the science literacy of all students while acknowledging that most students have interests and abilities that go beyond the common core, and some have learning difficulties that must be considered;
- Avoids language used for its own sake, in part to reduce sheer burden, and in part to prevent vocabulary to being mistaken for understanding;
- Is informed by research on how students learn, particularly how it relates to the selection and grade placement of benchmarks; and
- Encourages educators to recognize the interconnectedness of knowledge and to build these important connections into their curriculum units and materials.

The National Science Education Standards. An overview of the *National Science Education Standards* (NSES) reveals that both scientific literacy and inquiry are critical in order to compete in today's world and global economy. In fact, "more and more jobs demand advanced skills, requiring people to learn, reason, think critically, make decisions, and solve problems" (National Science Education Standards, 1998, p. 1; National Academies Press, 2009a, p. 1). An increased level of understanding of the core tenets on which science pedagogy is based will help elevate the level of instruction so that all students are conversant with the requisite skills essential for success. The core tenets formed as part of the NSES are as follows (National Science Education Standards, 1998, p. 19; National Academies Press, 2009b, p. 1):

- Science is for all students.
- Learning science is an active process.
- School science reflects the intellectual and cultural traditions that characterize the practice of contemporary science.
- Improving science education is part of systematic education reform.

Elaborating on the core tenets as listed above, all students regardless of age, color, creed, gender, race, or economic background, etc., should have the opportunity to experience science (as the constructivist view holds). As a part of the *National Science Education Standards*, it is also realized that students achieve their depth of knowledge in different ways and at different rates. Thus, an extended effort should be made to develop a curriculum that is developmentally appropriate and relevant to student's lives (National Science Education Standards, 1998, p. 20; National Academies Press, 2009c, p. 1).

In fact, developing a conceptual knowledge base in the subject of science requires that learning be an active process. Recursive in theme, the students are the primary stake holders and all must be willing participants in the process and not simply a watcher. It is clearly not adequate to design and implement a curriculum in which the focus is not on constructive advancement, the learning activities must include a “minds-on” component as well (National Science Education Standards, 1998, p. 20; National Academies Press, 2009c, p. 1).

The NSES emphasizes that high expectations are set for learning science and for establishing significantly higher levels of science literacy amongst the entire school-aged population inside the United States. In addition, students should develop an appreciation on how science has developed into a “way of knowing”. Students should also acknowledge that greater gains in one’s own learning will occur when they become involved in the personal and social perspectives of science (National Science Education Standards, 1998, p. 21; National Academies Press, 2009d, p. 1).

In summation of the four core tenets of the NSES, if the overall objective is to improve the current state of science education in the United States, it must emphasized that educators and teachers alike need to measure the depth and breadth of conceptual understanding of their students. It is not sufficient to rely on rote memorization or a blank recall of trivial facts to measure how much an individual understands. In addition, there also has to be a supplementary focus with long-term (positive) implications (National Science Education Standards, 1998, p. 21; National Academies Press, 2009d, p. 1).

Chemistry in the National Science Education Standards. It is important to note that the NSES does not define or characterize content for chemistry, however, because of its interconnectedness and the way it explains the "how" of other sciences, it acknowledges chemistry to be a central science (Carroll & Sherman, 2008, p. 17; Bretz, 2008). Due to this fact, the NSES has included in its standards, many concepts which are important to chemistry, which the American Chemical Society help draft. Although there is no directive to follow any sort of pedagogical constructs, inquiry is considered an important aspect to work into instructional practices. (Bretz, 2008).

Ultimately, the central goal of instruction is "improved student learning of central facts, ideas, and skills of chemistry" (Deters & Heikkinen, 2008, p. 8). Whatever the instructional technique utilized, it should "clearly contribute to improved science learning" (Deters & Heikkenen, 2008, p. 8). In this context, the instructional strategies used to address content issues are a means to an end. In fundamental terms the standards are the ends and not the means by which they may be reached (Deters & Heikkinen, 2008).

As schools transition and change emphasis to a standards-based curricular model, teaching and learning may be enhanced by becoming knowledgeable of major thematic frameworks (Kitzmann & Otto, 2008). Table 1 shows such a structure (adapted from Kitzmann & Otto, 2008, p. 22):

Table 1

Changing Emphasis of Chemistry Instruction

Less emphasis on	**More emphasis on**
Courses with little connection to other disciplines	Courses that incorporate connections to other sciences
Fragmented instruction that moves from topic to topic without connections	Integrated instruction that focsuses on fundamental concepts and processes
Concepts presented in isolation from real-world applications	Concepts and processes introdcued with a real-world context and explored in real-world applications
No coordination among all science disciplines to reinforce unifying themes and	Coordination throughout all grades and and all sciences in terms of introduction use of unifying themes

When incorporating the thematic constructs (as noted in Table 1) into the GPS chemistry curriculum, two unifying themes emerge, 1) Major Content Concepts and 2) Characteristic Concepts to Maintain, both are shown in Table 2 below (adapted from the Georgia Department of Education, 2009a):

Table 2

Georgia Chemistry Content and Characteristic Concepts

Major Content Concepts	**Characteristic Concepts to Maintain**
Classification of Matter	Records investigations clearly and accurately
Atomic Theory/Configuration	Uses scientific tools
Periodicity	Interprets graphs, tables, and charts
Bonding/Nomenclature	Writes clearly
Law of Conservation of Matter	Uses proper units
Empirical/Molecular Formulas	Organizes data into graphs, tables, and charts
Stoichiometry	Uses models
Kinetic Molecular Theory/Phase Changes	Asks quality questions
Gas Laws	Uses technology
Solutions/Concentrations	Uses safety techniques
Acid/Base Chemistry	Analyzes scientific data via calculations and inferences
	Recognizes the importance of explaining data With precision and accuracy

Unifying Themes in the Chemistry Performance Standards

It is noted by Kitzmann and Otto (2008) that instruction within the discipline of chemistry stands in stark contrast that that within others areas of science. Through the use of thematic commonalities students are provided the opportunity to develop experiential associations amongst chemistry itself and other areas (such as biology, earth science, and physics, etc.). Consequently the use of these unifying themes is also a way to approach the design of a course (such as chemistry) (Kitzmann and Otto (2008, p. 22) and assist in guiding instruction.

Although there are many instructional models which are often utilized or at least referenced when designing a curricular framework, the examples which were explicitly practiced during the course of this study included 1) The use of learning styles (VAK), 2) Understanding by Design (by Wiggins and McTighe) and 3) scientific inquiry. The utility of each methodology will be explained and analyzed for its value within chemistry itself at the LAHS. In addition, working examples will be provided to display how the information has been applied and differentiated for use within the classroom.

Learning Styles and Differentiated Instruction

According to Larkin (2003), there are many different descriptions of what actually constitutes a learning style. The physical act of defining such a resolute catchphrase can prove challenging because of the transposable nature of the term. “Learning styles” is also frequently used interchangeably with “cognitive style” and “learning strategy”. (Cassidy, 2004). Dunn (1990) defines a learning style as “…the way each learner begins to concentrate, process, and retain new and difficult information” (p. 224).

When evaluating individual (student) learning styles via any evaluative instrument, it is important to note that the profiles generated from such an activity are just suggestions of “behavioral tendencies rather than being infallible indicators of behavior” (Felder & Spurlin, 2005, p. 104). It has also been noted that despite one’s initial measured preference, an individual’s educational experiences can change this variable. A student in a course which provides experiential opportunities in all modalities (visual, auditory, and kinesthetic in the specific case of this study) will be more well-rounded and able to face the challenges of real-life outside the confines of a secured environment (such as school) (Felder & Spurlin, 2005).

The act of differentiating within the theme of learning styles provides a vehicle to enhanced learning and cognitive understanding. The term, *differentiated instruction*, is referred to as a "systematic approach to planning curriculum and instruction for academically diverse learners." (Tomlinson & Strickland, 2005, p. 6). Out of the five classroom elements Tomlinson and Strickland (2005, p. 6) mention as possible ways teachers can modify (or differentiate) curriculum, two methodologies (content and process) show great aptitude in chemistry. Content is what is taught and how students are given access to the essential core concepts while process is described as a particular course of action intended to achieve a desired result. Based upon the essential classroom elements noted, there are three students characteristics to which teachers can respond: 1) Readiness, 2) Interest, and 3) Learning Profile.

Table 3 (as adapted from Tomlinson and Strickland (2005, p. 9)) illustrates ways in which course content was specifically differentiated for varying student attributes in the study regarding *Assimilative Domain Proficiency and Performance in Chemistry Coursework.*

Table 3

Guide to Differentiating Content Based Upon Student Characteristics

Student Characteristic	**Strategy**
Readiness	Use small-group instruction to reteach students having difficulty. Use small-group instruction for advanced students. Demonstrate ideas or skills in addition to talking about them. Use texts with key portions highlighted. Provide organizers to guide note taking.
Interest	Provide materials to encourage further exploration of topics And interest. Use student questions and topics to guide lectures and Materials selection. Use examples and illustrations based on student interests.
Learning Profile	*Present material in **visual**, **auditory**, and **kinesthetic** modes. Use applications, examples, and illustrations from a wide variety of intelligences. Use wait time to allow for student reflection.

***Differentiating content according to visual, auditory, and kinesthetic modalities was an important element in this research report.**

Table 4 (as adapted from Tomlinson and Strickland (2005, p. 10)) illustrates strategies for differentiating according to process (which were utilized in this research study). As noted in Chapter 1, processing skills (as measured by the ACT) are seriously deficient for students at the LAHS.

Table 4

Strategies for Differentiating Process

Student Characteristic	**Strategy**
Readiness	Use tiered activities (activities at different levels of difficulty, But focused on the same key learning goals). Make task directions more detailed and specific for some learners and more open for others. Use both like-readiness and mixed-readiness work groups. Provide readiness-based homework assignments. Vary the pacing of student work.
Interest	Design tasks that require multiple interests for successful completion. Encourage students to design or participate in the design of some tasks.
Learning Profile	Allow multiple options of how students express learning. Encourage students to work together or independently. Balance competitive, collegial, and independent work arrangements. Develop activities that seek multiple perspectives on topics and issues.

Visual Modality. Students with a visual modality preference find that learning is most effective when mental imagery is utilized. These learners benefit from the use of concepts maps, graphs, pictures, and symbols, etc. (Bretz, 2005; McKeown, 2003; Sprenger, 2008). The use of color also shows additive benefits. According to Sprenger (2008, p. 9), "color activates the right hemisphere of the brain [and] since most of [what is done] in school is considered left hemisphere activity, [infusing color into classroom instruction] may assist the brain in using both hemispheres [of the brain] for learning."

Figure 11 demonstrates how content is differentiated for visually oriented students. The concept presented is the mol (pronounced mole) and two important key terms are defined while visual representations for each are given.

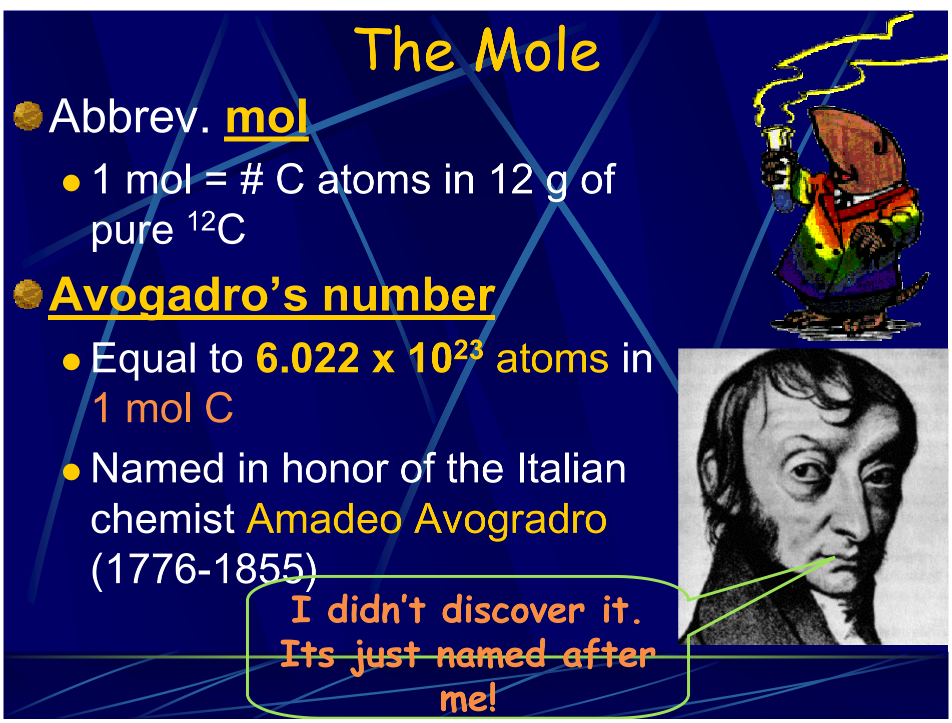


Figure 11. Chemistry notes regarding the mol concept differentiated by content for learners with a visual modality preference (from Byrnes, 2009a).

In Figure 12, numerical equivalencies for the mol concept are given along with six pictured examples. Here it is shown that although the masses of each of the samples are different, they all contain the same number of atoms.

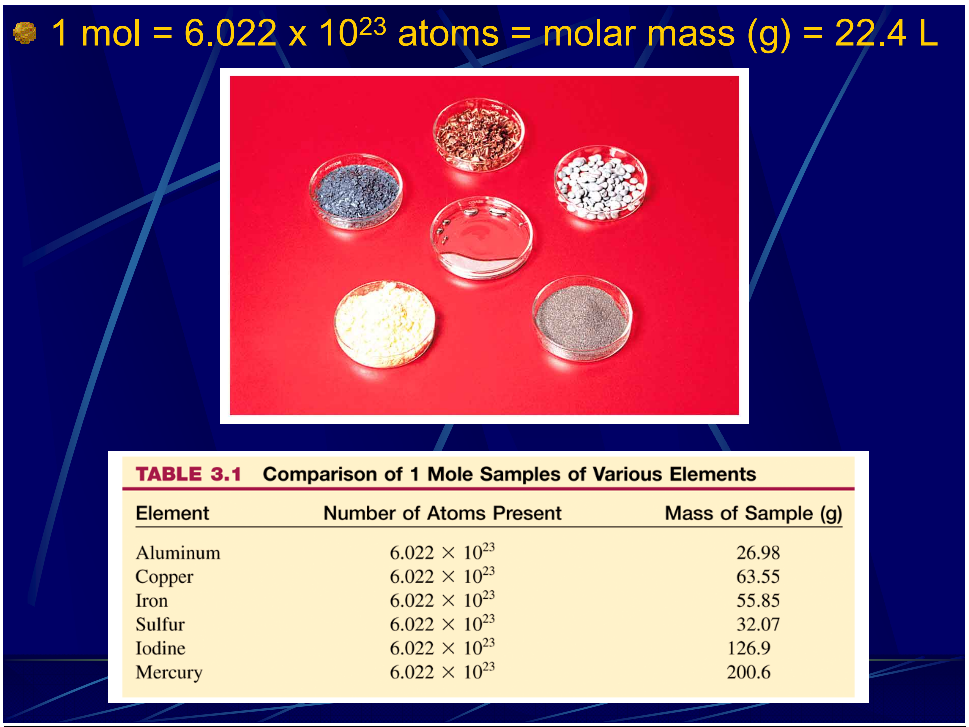


Figure 12. Chemistry notes showing the color-coded numerical mol equivalencies along with pictures and a chart comparing their masses and the number of atoms contained in each (from Byrnes, 2009a).

In Figure 13, a Venn Diagram graphically shows all the equivalencies used for converting within the mol concept.

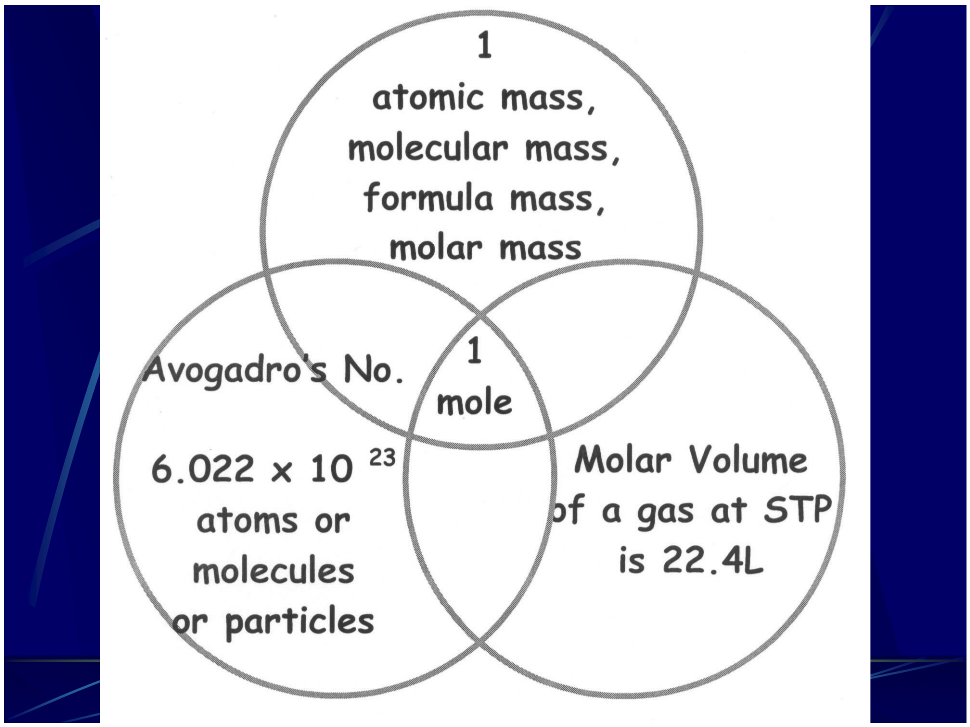


Figure 13. Chemistry notes showing a graphical (Venn Diagram) relationship amongst the variables used for converting within the mol concept (from Byrnes, 2009a).

Figure 14 shows a representation of how process is differentiated for visual learners. Sprenger (2008, p. 78) emphasizes that seeing the in print or in pictures is key in helping guide learning. Watching the process being performed also helps develop an individual's motor procedural memory. In this procedure, key stoichiometric terms are highlighted and basic instructions on how to convert grams of a reactant to grams of a product are given. A concept map is given with these important steps highlighted.

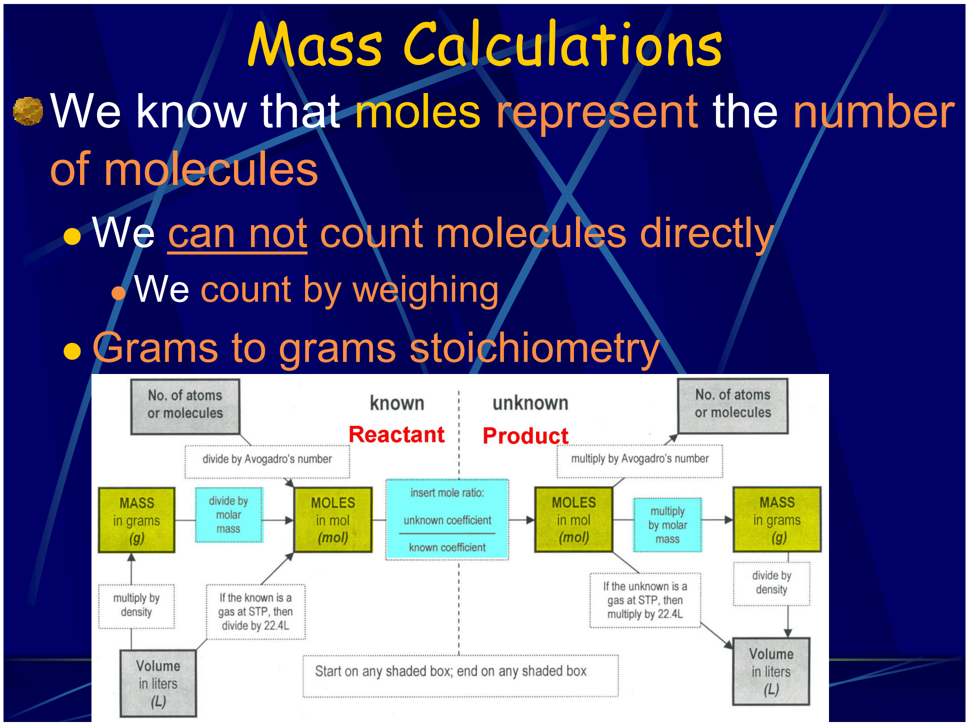


Figure 14. Chemistry notes showing how the stoichiometric procedure is differentiated by process for learners with a visual modality preference (from Byrnes, 2009c).

Figure 15 shows how the individual steps to the stoichiometric process shown in Figure 14 are applied to a specific problem. The calculated answer is shown along with how to round to the correct number of significant figures.

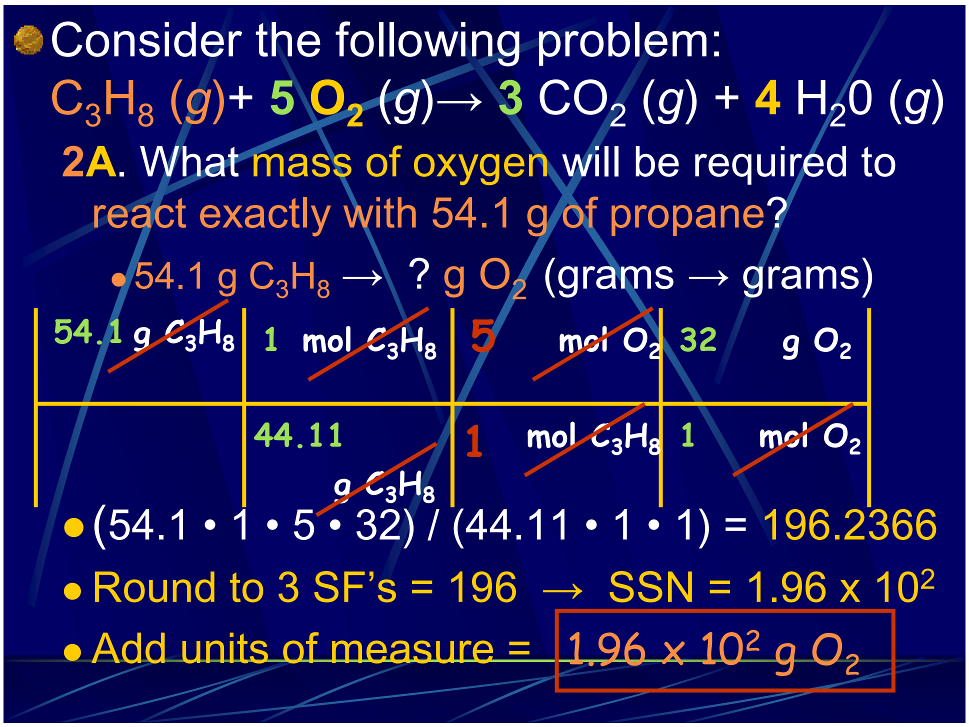


Figure 15. Chemistry notes displaying the process of how to solve a specific stoichiometry problem (from Byrnes, 2009c).

Certainly differentiating for the visual learner, whether it be by content or by process, can prove frustrating (especially in chemistry) if there is a lack of immediate feedback when applying the principles and concepts learned inside the classroom. Many times providing a solution to a problem is not merely sufficient if students are not able to remember the procedural aspects of the problem. Figure 16 shows an example of a tutorial exercise on how to convert a grams to grams stoichiometric problem. Students will have to apply the same concept as found in Figures 14-15. In this specific example, students obtain a new problem by pressing the appropriate button. If the correct solution is entered, a new problem will be displayed. If an incorrect solution is given three times, the procedure, as well as the final solution, will be displayed.

Using Balanced Chemical Equations-grams to grams

This page provides exercises in using chemical reactions to relate the masses of two substances. When you press "New Problem", a balanced chemical equation with a question will be displayed. Determine the correct value of the answer, enter it in the cell and press "Check Answer." Results will appear immediately in the scoring table.

New Problem

Enter your answer

Check answer Show answer

Results	Total Done	Total Correct
Incorrect	5	0

For the balanced equation shown below, how many grams of NaCl will be produced, if 22.6 grams of H_3PO_4 are produced?

$3HCl+Na_3PO_4 => H_3PO_4+3NaCl$

To answer this question, you use the mass ratio from the balanced equation between H_3PO_4 and NaCl

$NaCl/H_3PO_4=175.32/98=?/22.6$

Rearranging the equation and solving yields:
175.32/98*22.6=40.4

Figure 16. A stoichiometric review exercise which displays the required balanced chemical equation along with the procedure (broken down into segments) required to obtain the solution (from Byrnes, 2009d).

Auditory Modality. Students with an auditory modality preference benefit through the use of lectures and class discussions (Bretz, 2005). In many instances, when students in this grouping have difficulty learning a particular concept, they talk through the problem solving process (McKeown, 2003). Differentiating for content and process can be done in conjunction with both the visual (i.e., notes/procedural explanation) and the kinesthetic (i.e., involving movement) modalities.

Kinesthetic Modality. Students with a kinesthetic modality preference gain insight from personal experiences. Designed learning activities should be engaging in an effort to allow individuals to practice or try new things (Bretz, 2005; McKeown, 2003; Sprenger, 2008). As with the auditory modality, differentiating by content and process can be accomplished in association with the other modalities.

Figure 17 shows a kinesthetic cooperative learning exercise in which students are divided into groups to explain and demonstrate the problem solving process of how to convert one set of molar equivalencies into another. Here, students are encouraged to work together and are allowed the freedom of movement. It is the group's responsibility to ensure that all members are familiar with the problem solving process. After a predetermined time period, students will display their work to the class (via a markerboard) and explain their methodology. If any of the other class groupings fail to understand the explanation, any individual within the group can be selected to further elaborate.

Using the name of the compound below, list and be able to explain the following: A) Formula, B) Type (I, II, or III), C) Molar Mass, and D) The solution to the mol-type problem (with the correct number of significant figures). **Note**: Emphasize the use of key terms in your explanation and problem solving process.

Group I:	Beryllium phosphate	[1.2 mol Beryllium phosphate → atoms]
Group II:	Gallium selenide	[142 g Gallium selenide → mols]
Group III:	Ferric citrate	[7.24×10^{24} atoms Ferric citrate → grams]
Group IV:	Disulfur pentafluoride	[98 g Disulfur pentafluoride → liters]
Group V:	Tetranitrogen heptoxide	[21 L Tetranitrogen heptoxide → grams]
Group VI:	Plumbous carbide	[8.92×10^{26} atoms Plumbous carbide → mols]

Figure 17. A stoichiometric cooperative learning exercise designed for students with a kinesthetic modality preference.

Putting the Styles Together. To summarize, an individual learning style is the manner and conditions in which "learners most efficiently [and] effectively perceive, process, store, and recall what they are attempting to learn" (Lujan & DiCarlo, 2006, p. 13). The Learning Preference Checklist, also referred to as the VAK, is a model which characterizes these sensory preferences. An addition to this model, made by Neil Fleming in 1987, split the visual dimension into two parts: 1) V - represents the symbolic portion and 2) R - represents the in-text portion (also known as reading/writing) (Fleming, 2009). Whether it is the VAK and or the VARK, the impetus was to determine the differentiated techniques needed to address all students and not a select few.

Much of the research on modality preferences shows an inordinate number of individuals are multimodal, thus they prefer presentation in many modes to fully understand conceptual aspects (Fleming & Baume, 2006, p. 5). Research gathered by Neil Fleming showed that about 40% of respondents (on average) are multimodal (Sankey, 2007, p. 61). The results of an individual study carried out on first-year medical students at Wayne State University in 2005 showed that 64% (much higher than 40%) identified themselves as multimodal (Lujan & DiCarlo, 2006, p. 14). Through these studies an underlying assertion can be made that knowing a student's preferred modality can enrich the learning experience and there should not be a concentrated focus on any one particular modality when designing a curriculum.

A study conducted by Wantanabe, Nunes, Mebame, Scalise, and Claesgens (2007) showed that when a curriculum is differentiated to meet the needs of a wide array of ability levels, as was the case at an individual California high school where the chemistry classes were detracked (to 1 level), significant gains can ensue. In this particular instance a *t*-test analysis of pre- and posttest data showed a significant gain ($p < .001$) as compared to years where multiple levels of chemistry were offered and less effort was made accommodate learning preferences. Likewise, a chemistry mini-project study conducted by Bahar (2009) also showed that learning styles can impact student scores. Due to the framework, those students whose preferred learning modality matched the essential components of the project showed statistically higher scores than those whose learning preferences were not addressed (as a result of a Multivariate Variance of Analysis).

Effectively utilizing the VAK can also help in transitioning students between conceptual knowledge and practical application. A study conducted by Arasasingham, Taagepera, Potter, and Lonjers (2004, as stated in Fier, 2007, p. 22), found that a need exists in helping students integrate knowledge between the physical phenomena to the actual language of chemistry and mathematical models. In other words, from the macroscopic level, to microscopic (representative of the particle level), and then to the symbolic level (Nahum, Hofstein, Mamlok-Naaman, and Bar-Dov, 2004, pp. 303-304). Prior research on this matter conducted by Robinson (2003 as found in Fier, 2004, pp. 23-24), showed that when extra emphasis is made by teachers to explain the integration of the foundational chemical aspects, increased knowledge and higher test scores will ensue. In this particular instance, improvement scores on a series of stoichiometry exams were statistically significant ($t = 2.3853$, $p < .05$).

Understanding by Design

Understanding by Design (as developed by Grant Wiggins and Jay McTighe) presents a framework for curriculum design and implementation by which students develop a deeper holistic understanding of the conceptual aspects of the subject matter (in this case chemistry) (Brown & Wiggins, 2004; Wiggins & McTighe, 2005). Although grandiose in structure, *Understanding by Design* is based upon the following key tenets (McTighe & Seif, 2003, p. 1):

1. A primary goal of education is the development and deepening of student understanding.
2. Evidence of student understanding is revealed when students apply knowledge and skills within authentic contexts.
3. Effective curriculum development reflects a three-stage design process called "backward design." This process helps to avoid the twin problems of "textbook coverage" and "activity-oriented" teaching in which no clear priorities and purposes are apparent.
4. Regular reviews of curriculum and assessment designs, based on design standards, are needed for quality control, to avoid the most common design mistakes and disappointing results. A key part of a teacher's job is ongoing action research for continuous improvement. Student and school performance gains are achieved through regular reviews of results (achievement data and student work) followed by targeted adjustments to curriculum and instruction.
5. Teachers provide opportunities for students to explain, interpret, apply, shift perspective, empathize, and self-assess. These "six facets" provide conceptual lenses through which students reveal their understanding.
6. Teachers, schools, and districts benefit by "working smarter" – using technology and other approaches to collaboratively design, share, and critique units of study.

Within the aforementioned tenets, the design structure is characterized by three overarching themes: 1) Backwards Design, 2) The use and development of *essential questions*, and 3) Applying scope and sequence to a curriculum for understanding.

Backwards Design. The backwards design concept has additive benefits in the field of curriculum development because in so many instances, teachers begin with the local designated textbook as the primary material source as compared to secondary resource. Teachers also commonly supplement textbook material with favorite lessons and activities rather than deriving these from the state standards (Wiggins & McTighe, 2009). The current design structure begins with the end in mind (or the desired results) and then "derives the curriculum from the evidence of learning (performances) called for by the standard and the teaching needed to equip students to perform" (Wiggins & McTighe, 2009, p. 2). The three stage design process is shown in Figure 18 (as adapted from Wiggins & McTighe, 2005, p. 18):

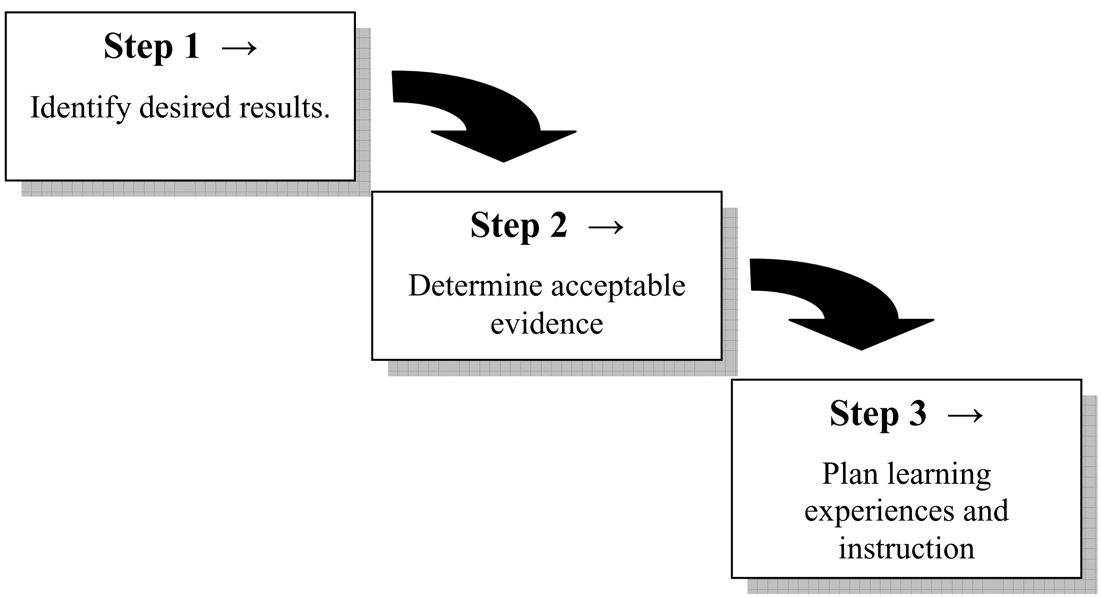


Figure 18. The three stages of backwards design in Understanding by Design (as adapted from Wiggins & McTighe, 2005, p. 18).

The first stage in this process (identify desired results) necessitates clarifying priorities. Here, the conceptual aspects expected of students should be determined. In many cases, this may entail “unpacking” the standards in order to uncover the core concepts which need to be addressed (McTighe & Thomas, 2003, p. 1; Wiggins & McTighe, 2005).

The second stage (determine acceptable evidence) requires curriculum designers to envision the required assessment documentation unit by unit and plan within this context. This documentation is necessary to confirm that the desired level of learning has taken place (Wiggins & McTighe, 2005).

In the third and final stage (plan learning experiences and instruction), choices regarding the specifics of lesson planning must be made. Depending upon the assessed level of knowledge and prior experiences of the students, certain methods of teaching may need to be altered, along with the sequencing of lessons, and the selection of alternative resource materials. This can only take place after the prior two stages have been successfully navigated (Wiggins & McTighe, 2005).

Essential Questions. An *essential question*, as defined by Wiggins & McTighe (2005, p. 342), “is a question that lies in the heart of a subject or a curriculum (as opposed to being either trivial or leading) and promotes inquiry and uncoverage of a subject.” Typically these all-encompassing questions are recursive in nature and should be designed to highlight the *big ideas,* which in most cases are framed across multiple units. These questions form the foundation by “which learners explore key concepts, themes, theories, issues, and problems that reside with content (Wiggins & McTighe, 2005, p. 106).

Essential questions should be designed in such a manner that "promote[s] conceptual connections and curriculum coherence" (Wiggins & McTighe, 2005, p. 108). The construction of the questions can be done in conjunction with Bloom's Taxonomy depending upon the learning objectives of the unit in question. Table 5 (as adapted from Felder & Brent, 2004, pp. 8-9), shows the Bloom's Taxonomy level along with a description of the level. Also included are the key terms associated with each level and an example of a questions specific to chemistry using said key term.

Table 5

Chemistry Essential Questions/Statements with the Associated Bloom's Level Descriptive Key Term

Bloom's Taxonomy Level	**Level Description**	**Key Term**	**Chemistry Example**
1	Knowledge	List	**List** the first ten alkanes.
		State	**State** the steps in the procedure for calibrating a gas chromatograph.
2	Comprehension	Explain	**Explain** in your own words the concept of vapor pressure.
		Interpret	**Interpret** the output from an ASPEN flowsheet simulation.
3	Application	Calculate	**Calculate** the probability that two sample means will differ by more than 5%.
		Solve	**Solve** the compressibility factor equation of state for *P*, *T*, or *V* from given values of the other two.
4	Analysis	Derive	**Derive** Poiseuille's law for laminar Newtonian flow from a force balance.
		Explain	**Explain** why we feel warm in 70°F air and cold in 70°F water.
5	Synthesis	Formulate	**Formulate** a model-based alternative to the PID controller design presented in Wednesday's lecture.
		Make up	**Make up** a homework problem involving material we covered in class this week.
		Design	**Design** anything!
6	Evaluation	Determine	**Determine** which of the given heat exchanger configurations is better.
		Select	**Select** from among available options for expanding production capacity, and justify your choice.
		Critique	**Critique** an essay, report or article for accuracy and style.

Table 6 shows an example of a big idea encompassing an entire unit in chemistry (Buthelezi, et al., 2008, p. 514A) and the associated essential questions for the unit (Byrnes, 2009e). Although varied, comparisons with the key terms used to differentiate different levels of cognitive development can be drawn from the Bloom's Taxonomy terms listed in Table 5.

Table 6

Big Idea and Essential Questions for an Energy and Chemical Change Unit

Big Idea: Chemical reactions usually absorb or release energy.

Question Letter	Key Term	Comparison Term	Bloom's Level	Essential Question
A	Distinguish	Derive	4	**Distinguish** between potential and kinetic energy.
	Example	State/List	1	Give an **example** of each.
B	Differences	Explain	2	What are the **differences** between temperature and heat?
	How	Explain	2	**How** is each measured?
	What	State/List	1	**What** are the units of measurement for each?
C	What	State/List	1	**What** is the equation used for calculating the amounts of heat gained or lost in a chemical reaction?
	Define/Give	State/List	1	**Define** and **give** the units of measurement for each of the variables.

D	Describe	Interpret	2	**Describe** how a calorimeter is used to measure energy that is absorbed or released.
E	Explain	Explain	4	Briefly **explain** the meaning of enthalpy and enthalpy change in chemical reactions and processes.
F	What Calculated	State/List Calculate	1 3	**What** is Hess' Law and How is it **calculated**?
G	Differentiate	Evaluate	6	Differentiate between spontaneous and nonspontaneous processes.

Applying Scope and Sequence for Understanding. According to Wiggins and McTighe (2005, p. 294), the often used curricular phrase, *scope and sequence*, has become synonymous with the "logic of the curriculum." The origins of the logical sequencing of curriculum can be traced back to constructivist theorists John Dewey and Hollis Caswell, a Dewey protégé, and although the original connotation has changed, in this pursuit it is meant to help purveyors of any subject matter present material which would seem most natural from the perspectives of the learners themselves.

The logical sequencing of curricular components should follow a process by which all learners are first exposed to the conceptual aspects of the subject matter and then are able to receive adequate practice in applying the core principles (which are framed by the big ideas and essential questions). Students should also be given ample time to reflect upon these practices so adjustments (from both the student and the teacher) can be made to help increase the level of understanding. Subject matter aside, the following attributes should serve as a guide:

> "(1) backwards design from explicit performance goals, with work adjusted constantly in response to feedback from learners and performance results; (2) a constant and frequent movement between an element and performance (learning and using discrete knowledge and skill) and the whole complex task that prioritizes and justifies the learning; (3) a regular movement back and forth between being instructed and trying to apply the learning; and (4) a sequence that enables learning from results, without penalty, before moving on and becoming ready to formally perform" (Wiggins & McTighe, 2005, p. 291).

The redesign of the science curriculum to a performance standards system (GPS) in Georgia is supported by the aforementioned aspects. The curriculum map for the LASS (adapted from Coweta Schools Intranet, (2009)) in Appendix B, shows the chemistry scope and sequence for both the general and advanced levels. It is broken down into four $4^{1/2}$ week segments for use within the block scheduling system. The conceptual components are listed as column headings with the key curricular concepts following. Modifications specific for both the advanced and general levels are marked with different symbols. It should be noted that each of these four segments is constructed to stand alone and may be taught in any order, however, the order as presented is a progression which would seem most logical to the learner them self.

Scientific Inquiry

There is ample evidence to affirm the standpoint that students at the LAHS have issues with processing and applying abstract scientific concepts, as measured primarily by scores on the ACT-SRP (See Figure 2) and middle school CRCT – Science Portion (see Figure 8) standardized evaluations. Much of this has to do with the manner by which students approach learning in their respective science courses. If implemented effectively, students who are exposed to the methods of scientific inquiry (third unifying theme) will learn to “formulate good questions, identify and collect appropriate evidence, present results systematically, analyze and interpret results, formulate conclusions, and evaluate the worth and importance of those conclusions” (Prince & Felder, 2006, p. 9). Likewise, students will become content masters through their own self-construction. This will enhance crucial learning skills (i.e., critical thinking and problem solving) (Trout et al., 2008, p. 33) with the end result being an increase in standardized test scores (like on the ACT – SRP and the CRCT – Science Portion).

Scientific inquiry itself is more formally defined as the “evidence-based process that scientists engage in to study and propose explanations about the natural world” (Trout et al., 2008, p. 30). It is formally comprised of three essential components: 1) Learning about the nature of science and the work that scientists do, 2) learning to do science (which means developing the abilities to design and conduct scientific investigations) and 3) understanding scientific concepts and principles (Trout et al., 2008, p. 30). The inductive nature of the inquiry process takes on many different forms (i.e., structured, guided, open, teacher) as discussed by Prince and Felder (2006), but Process-Oriented-Guided-Inquiry-Learning (POGIL) is the most widely used in chemistry curricula.

POGIL is where "the instructor serves as facilitator, working with student groups if they need help and addressing class-wide problems when necessary" (Prince & Felder, 2006, p. 9). The goal of this methodology is to properly balance the traditional scientific lecture with self-discovery learning by which students take a large measure of responsibility for their own learning (Trout et al., 2008, pp. 30-31).

Activities designed to support this process follow the cyclical curricular framework as supported by Kolb's ELT (see Figure 10). The first and second phases in the POGIL learning cycle correspond to the Assimilating quadrant by which there is acquisition of new knowledge and concepts. Inductive questioning assists in leading students towards pattern or trend identification. A certain level of conceptual development also takes place during this stage. The third phase occurs in the Converging quadrant where applicative skills are practiced. This structure allows students to take a sense of ownership in the learning process while reinforcing the integral aspects of the scientific inquiry process (Trout et al., 2008, p. 33).

Evaluation of the POGIL Methodology. A review of the literature and experimental studies carried out regarding the implementation of POGIL methodologies from the middle grades through college, as reported by Lee (2004, p. 10) and Shymansky, Hedges, & Woodsworth (1990, p. 10), showed that there were four commonalities regarding outcome: 1) Improved critical thinking skills, 2) greater capacity for independent inquiry, 3) taking more responsibility for one's own learning, and 4) intellectual growth (as measured on the Perry Scale). Research studies conducted by Deborah Smith (1996) specifically measured the effect size of a couple of the aforementioned common outcomes. Inquiry-based methodologies had the largest effect on improving critical thinking skills (effect size = 0.77), while improved academic achievement was shown to be slightly less effective (effect size = 0.33). However, only a slight change in the ability to process scientific information was measured (effect size = 0.05).

Research conducted by Rubin (1996, as found in Prince & Felder, 2006) found that conceptual learning, reasoning ability, and creativity were superior when inquiry-based instruction was utilized (effect size = 0.18). There was even a marked improvement in non-cognitive skills, such as manipulative skills and attitudes (effect size = 0.39). The research conducted by Colburn (2009) concluded that such inductive methods accentuate a student's understanding of observable phenomena, but lacks somewhat in helping students understand how scientists process information (which is a critical factor in developing an individual's scientific habits of mind). Improvements in this element can be achieved through asking probing questions, the answers of which can be determined through personal investigation(s) or laboratory activities. However, it is noted that the questions and related activities should be designed in such a manner as to accentuate a student's prior knowledge base, but be challenging enough to develop their cognitive abilities.

Analysis of Research Methodology

The use of O'Brien's (1990) Learning Preference Checklist (VAK) or Fleming's VARK as a diagnostic tool to determine an indivdiuals preferred learning modality is well supported in the literature. These evaluative instruments use the outcome to create an awareness amongst the students themselves as well as the teachers. The results also provide an avenue in which ceratin curricular aspects, including instruction, can be modified be accentuate associated strengths while addressing the subject specific standards (Carbo & Hodges, 1988; Fleming, N.D, 1995; Fleming, N.D. & Baume, D., 2006; Fleming, N.D. & Mills, C., 1992, O'Brien, L., 1989).

The use of the preexperimental one-group pretest-posttest design (e.g., Group A: $O_1 – X – O_2$) research methodology, as described by Creswell (2003, p. 168), is the strategy that is most conducive to determine if the curricular modfications made in the *Assimilative Domain Proficiency and Performance in Chemistry Coursework* study are effective, both statistically and cognitively. In a critical review of research studies which investigated the effects of instructional methods on changes in levels of critical thinking (specifically in college students), it was found that 25 of the 27 indivdiual studies employed a one group pretest-posttest design strategy (McMillan, 1987). In specific studies revolving around chemistry and the relative effectiveness of concept mapping in the classroom and laboratory settings, both Ozmen, Demircioglu, and Coll (2009) and Lehman (1985) employed the one-group pretest-posttest design method.

The justification for the use of the KLSI to measure cognitive development as a correlative comparative is also bolstered by similar work conducted by Kolb & Kolb (2005a-b), Kolb (1984), and also, according to Prince & Felder (2006) by Shymansky et al. (1990) and Smith (1996), regarding inquiry-based learning. The latter also promoted the use of effect sizes to measure the strength of the relationship between the two variables. The Pearson *r* correlation is the most commonly approach used in this type of inferential statistical study. The VAK will be further utilized in this process to determine if the curriculum (as it stands) needs to be further differentiated for students with a particular modal preference.

Transition

Through this literature review, it has been shown that students are personified by their varying learning styles. These individual styles serve as "indicators of how learners perceive, interact with, and respond to …[their]… learning environment" (Felder & Brent, 2005, p. 58). To improve critical thinking skills, instruction should be designed in a manner as to accentuate an individual's perceived learning modality, yet be challenging enough to promote intellectual growth in other modal zones. This can prove arduous in a subject matter such as chemistry because there are inviolate scientific laws and principles which have to be followed. In many instances there are best instructional practices and or strategies which have to be adopted because there is no alternate method (i.e., counting atoms).

The implementation of the GPS standards into the frameworks has not yielded the results intended. Scores on state-mandated and national tests at the LAHS are below local, state, and national levels. With tests being modified to represent the changes, there should be even a greater focus on applying concepts and underlying principles. The infusion of curricular components, such as *Understanding by Design* by Wiggins & McTighe and the POGIL inquiry methodology, can definitely help in this process. Perhaps the principal focus should lie in monitoring an individual's developmental progression as they transition through a course (such as chemistry) rather than waiting on scores, which may not arrive until the end of the semester or school year. Effectively utilizing the KLSI serves this basis, the underlying foundations of which lie upon Kolb's ELT.

CHAPTER 3:

RESEARCH METHOD

Introduction

This study investigated the impact of learning styles on students' cognitive development in chemistry and how they might modify ways students solve problems of increased complexity and rigor. The goal of this investigation was to differentiate the chemistry curriculum within the boundaries of local, county, and state GPS curriculum mandates in such a manner that students in each of the learning modalities can attain increased scores on chemical-content related standardized tests while concentrating on the application of the concepts and the development of scientific habits of mind. A secondary goal was to have students significantly shift their learning preference towards the Assimilative domain according to the KLSI, a region where undergraduate learning style (in the chemistry realm) matches that of the professor's. When the learning style of the student matches the method of delivery of the instructor, an increased level of personal satisfaction and learning can take place.

Included in this section are a description and justification for the research design and approach. The setting and population sample is described and defended. The treatment used to classify students into their preferred learning modalities is described in detail along with the two pre- and posttests which were administered. The process for determining the reliability and validity of each of these measures is addressed. Next, an explanation of the methods used to analyze the data is shared. Finally, the measures taken to protect the rights of the participants are summarized.

Research Design

This research study followed a preexperimental one-group pretest-posttest design described by Creswell (2003, p. 168). As diagrammed (e.g., Group A: $O_1 – X – O_2$), the X represented the exposure of the group in question to the experimental process differentiated according to learning style, while the O_1 and O_2 variables represent the administration of the KLSI and chemistry concepts pre- and posttests respectively (Creswell, 2003, p. 167-168; Johansson, 2004, pp. 21, 23). The focus of the study concentrated on students' transformation towards the Assimilative domain according to the Kolb Learning Style Inventory which according to according to Hudson (1966, as found in Kolb, 1984) and Kolb (1984, p. 86), is a region of development commonly held by undergraduate chemistry majors (see Figure 5). Determining the learning dimension of students could assist in establishing connections which help link their knowledge of the concepts with prior experiences, which in turn could promote advancement into the critical thinking realm.

The following research questions and hypotheses were answered during this process:

Research Question 1

Can modifying high school chemistry curriculum to accentuate a student's learning preference affect a shift towards the Assimilative domain according to the Kolb Learning Style Inventory?

Null Hypothesis 1

Modifying a high school chemistry curriculum to accentuate a student's learning preference will not affect a significant shift towards the Assimilative domain according to the Kolb Learning Style Inventory.

Alternative Hypothesis 1

Modifying a high school chemistry curriculum to accentuate a students learning preference will affect a shift towards the Assimilative domain according to the Kolb Learning Style Inventory.

Research Question 2

Is there a correlation between the improvement in student learning (as measured by the difference in pre- and posttest scores on a chemistry-concepts diagnostic) and shift towards the Assimilative domain in the Kolb Learning Style Inventory?

Null Hypothesis 2

There is not a significant correlation between the improvement in student learning (as measured by the difference in pre- and posttest scores on a chemistry-concepts diagnostic) and shift towards the Assimilative domain in the Kolb Learning Style Inventory.

Alternative Hypothesis 2

There is a significant correlation between the improvement in student learning (as measured by the difference in pre- and posttest scores on a chemistry-concepts diagnostic) and shift towards the Assimilative domain in the Kolb Learning Style Inventory.

Research Approach

In this study, students were randomly assigned to two chemistry classes (through one instructor) by the guidance department at the LAHS. Recommendations for placement were made by individual teachers during the prior academic school year, and it was at the discretion of those teachers to determine the readiness and whether the students had met the determined prerequisites. The level of differentiation needed varied between the classes (to a degree) and was dependent upon the prior level of knowledge and conceptual development attained.

All students took the Learning Preference Checklist (VAK), as developed by O'Brien (1990), after the principal investigator received permission from the Walden Institutional Review Board (IRB approval # 10-30-09-0350479) to conduct research. The VAK was utilized to determine the students' preferred learning modality (either visual, auditory, or kinesthetic). The ensuing day, the first administration of the Kolb Learning Style Inventory (KLSI) was issued in conjunction with a 30 question (multiple choice format) chemistry concepts pretest. The KLSI was utilized to determine each student's Kolb learning style – Abstract Conceptualization, Active Experimentation, Concrete Experience, or Reflective Observation. The chemistry concepts pretest (Test A – see Appendix C) was constructed from questions selected from released versions of the New York Regents – Physical/Chemical Setting exams. The selected questions covered concepts which were taught during a nine week time frame. Accommodations were made for students who were absent during either of the administrations.

Once the preferred learning modalities were determined, homogeneous modal groups were assembled (as best that could have been arranged) for the purposes of classroom instruction and laboratory sessions. The chemistry curriculum was then differentiated based upon the students' preferred learning modality. At the end of the evaluative period, the chemistry concepts posttest (Test B – see Appendix E) was administered to the students in conjunction with the second administration of the KLSI. Test B was composed of different questions from released version of the New York Regents Physical Setting – Chemistry exam covering the same GPS components as was in Test A (see answer and standards comparisons in Appendices D and F respectively). The KLSI did not change in its composition.

Setting and Sample

The study took place at a LAHS located approximately 35 miles southwest of Atlanta, Georgia. It is one of three high schools in Georgia's Local County School System (LCSS). The LCSS has 6 middle schools, 18 elementary schools, one alternative school, one night high school, and one charter school (Governor's Office of Student Achievement, 2007e). Three middle schools send students to the LAHS. Two of these schools are located in the rural portion of the county, while the third is located in the more affluent section of the county. At the inception of the study, the student population was 2,324 (Governor's Office of Student Achievement, 2009b). Special education students (n = 292) made up 12.6% of the student population (Governor's Office of Student Achievement, 2009g). The population of the Local County according to the United States Census Bureau year 2000 statistics was 89,125. Yet a recent 2006 estimate shows that the population had grown to about 115,291, which represents a population increase of 26,166 residents in 6 years. The breakdown by race is as follows: 80.7% - white, 17.0% - black, 1.0% - Asian, 1.0% - two or more races, and 0.2% - American Indian or other pacific islander (United States Census Bureau, 2006).

The study population consisted of a randomized sampling of 47 students determined by the guidance department at the LAHS. Due to the specific context of the study, the students were limited to one instructor in two different class periods. According to the sample size calculator from Creative Research Systems (2009), a sample size 42 students were needed to participate to obtain a 95% confidence interval with a 5% chance of error. A student sample of below this number is justified and defended by Bacchetti, Wolf, Segal, & McCulloch (2005), who stated, “If there is no projected net burden [on the study participants], then any sample size is ethical, and sample size can be determined entirely by other considerations” (p. 106). The grouping for the sample was set at the general chemistry level, the eligibility requirements of which include any student in grades 10-12 who has passed Biology as an entry level science class in the 9th grade. Suggested prerequisites to this course as listed by the LCSS also include Math I (Algebra/Geometry/Statistics) and Math II (Geometry/Algebra II/Statistics) (Coweta County School System, 2009, pp. 61, 67).

Instrumentation and Materials

The Learning Preference Checklist (VAK)

The Learning Preference Checklist (O'Brien, 1990), is a randomized 36 question inventory in which the user classifies his response to different learning situations with numbers ranging from a five (5 – almost always) to a one (1 – almost never). Upon completion of the survey, the user transposes the scores from the front side of the sheet into one of three categorized sections (visual, auditory, or kinesthetic - VAK) on the back, with the highest score being a 60. From this point, percentages for each 12 question category are calculated and the perceived preferred learning style for the user is determined. The more even a profile is, the more adaptable students will be adaptable to other learning styles. Sample questions for each modality are as follows:

a) Visual: I can remember something better if I write it down.
b) Auditory: When reading, I listen to the words in my head, or I read aloud when possible.
c) Kinesthetic: I don't like to listen or read directions; I'd rather just start doing.

Learning Modality Descriptors. Visual learners are those students who picture in their mind what is being described. They have great recollection of what they have read or observed. They prefer to interpret information through illustrations (i.e., pictures, charts, diagrams) and appreciate a pleasant learning environment. These students are typically neat and organized (McKeown, 2003; *Students and sensory modality preference*, 2006).

Auditory learners prefer to listen and find great value in the more traditional methods of teaching where lectures are the preferred mode of instruction. These learners find significance and meaning in the instructor's explanations (the more detailed, the better). They are conscious of the speech patterns of the instructor and need to be reminded of important points rather than reading directions for themselves (McKeown, 2003; *Students and sensory modality preference*, 2006).

Kinesthetic learners are *tactile* in nature and need to be actively involved in the classroom setting. They do not thrive in an environment that is *static*. These learners are most successful in situations where they can practice and apply what they are experiencing (McKeown, 2003; *Students and sensory modality preference*, 2006).

Threats to Validity and Reliability. The Learning Preference Checklist (VAK), as designed by Lynn O'Brien (1990), has been found to have a high degree of reliability (when measured against a sample size of 107 high school students). The Cronbach alpha coefficient for this test grouping was .98, when corrected with the Spearman-Brown prophecy formula (split half reliability coefficient). Learning modality subgroupings (visual, auditory, and kinesthetic) were found to have reliability factors of .62, .62, and .69 respectively (Jaeger, 1993; O'Brien, 2009). As stated by Richard Jaeger (1993), utilizing this methodology (Spearman-Brown) does not show the stability of the measurement procedure over time. In addition, it will not reflect errors that arise from the administration at a particular time and or place. As a result, true reliability levels may tend to be overestimated.

As applied to its use in the current study, the validity of the VAK was controlled internally through consistency of use as a diagnostic tool to differentiate the curriculum. External validity of the instrument was controlled through differentiating the curriculum in all three learning modalities. However in must be noted that whatever the effects of reliability outcomes and or validity studies may imply, the intention of using a diagnostic device such as the VAK is not to type people, but to better understand the way individuals learn so "teaching and learning experiences can be provided to help [people] learn more effectively" (Learning and Teaching Scotland, 2005, p. 1).

The Kolb Learning Style Inventory (KLSI)

David Kolb's Learning Style Inventory (Version 3.1) revised in 2005, was used at the beginning of the study in conjunction with the VAK (O'Brien, 1990), to identify the learning styles of the students. Like the original, the updated version of the KLSI is also based upon the ELT and is "designed to help individuals identify the way they learn from experience" (Kolb & Kolb, 2005b, p. 1). The KLSI itself is a self evaluative instrument consisting of 12 questions concerning different learning situations. Respondents are required to rank order sentence endings (from 4 – most like you; to 1 – least like you) which correlate Kolb's dimensions to learning styles. Kolb's learning dimensions are as follows: (a) Active Experimentation (AE), (b) Concrete Experience (CE) – Experiencing, (c) Reflective Observation (RO) – Reflecting, and (d) Abstract Conceptualization (AC) – Thinking (Kolb, 2005). Kolb's learning styles include (a) Converger, (b) Accommodator, (c) Diverger, and (d) Assimilator (Kolb, 2005) (See Figure 4). Convergers are best at applying what they have learned to new situations; accomodators are kinesthetic in nature and gain insight from practical experience; divergers offer varying and different perspectives, while assimilators can look at a wide range of information and place it into a concise and logical form (Kolb, 2005; Loo, 2004). Determining the learning dimension of the student will assist in establishing connections which help link their knowledge of the concepts with prior experiences, which in turn will promote their advancement into the critical thinking realm.

Theoretical Constructs of the KLSI. The KLSI was primarily based upon descriptive models of learning originally proposed by Lewin and Dewey, and structurally enhanced by Piaget. There are two structural dimensions of cognitive development: (a) phenomenalism/constructivism and (b) egocentrism/reflectivism, with the prior representing a lower form of "knowing." Kolb (1984) proposes "…that the poles of these two dimensions are equipotent modes of knowing that through dialectic transformations result in learning" (p. 40). Kolb (1984) also notes that learning continues to proceed along a third (developmental) division "that represents not the dominance of one learning mode over another, but the integration of the four adaptive modes" (p. 40) and the way the *dialectics* get resolved (p. 41).

The basis of formation of the KLSI shows that there are two dialectically opposed forms of *prehension* (modes of grasping experience): (a) Abstract (*comprehension*) and (b) Concrete (*apprehension*). There are also two opposed ways of transforming that *prehension*. The result is four different modes of knowledge (Kolb, 1984) (see Figure 4).

Kolb (1984, p. 42) states that:

> "Experience grasped through *apprehension* and transformed through intention results in what will be called *divergent* knowledge. Experience grasped through comprehension and transformed through intention results in *assimilative* knowledge. When experience is grasped through comprehension and transformed through extension, the result is *convergent* knowledge. And when experience is grasped by apprehension and transformed by extension, *accommodative* knowledge is the result."

The modes of *prehension* have their foundational basis in brain-based research. According to Edwards (as found in Kolb, 1984), the left hemisphere of the brain corresponds to the *comprehension* process; it is abstract, analytical, linear, logical, and rational in nature. Correspondingly, the right hemisphere of the brain corresponds to the *apprehension* process; it is analogic, concrete, holistic, intuitive, nonrational, spatial, and synthetic. Bogen (as cited in Kolb, 1984), states that the "transformation process may be reflected in a front-to-back placement of the brain" (p. 56). The KLSI (overall) represents the synthesis of sound educational learning models supported with researched-based knowledge of the brain and how it functions.

Furthermore, a key function of this research design and methodology was to attempt to shape students' attitudes and orientations towards learning. It is clearly demonstrated that an individual's educational experiences do have an influence on one's preferred learning style, the seriousness of which begins (in earnest) during the high school years and develops in greater depth as one moves through classes which rely on greater amounts of applicative processing skills (Kolb, 1984).

A result of the research done by Kolb (1984) shows that "one's undergraduate education is a major factor in the development of his or her learning style" (p. 88). People choose fields of study which are consistent with their learning styles and are further shaped to fit these standards of their chosen field once they are fully entrenched in it. When there is a mismatch between the field's learning norms and an individual's learning style, people will either change specialties or leave the field altogether.

Scoring and Scales. The scores for each of the learning style types – Accommodating, Assimilating, Converging, and Diverging (see Figure 4) are created by dividing the AC-CE and AE-RO scores at the 50th percentile and plotting them on a four quadrant scoring grid (see Figure 5). The center of the grid does not correspond to an X and Y value of (0,0). The cut-off point for the AC-CE and AE-RO scales is (approximately) +7 and +7 respectively. Table 7 below shows the scores needed in order to qualify for each learning style type (Kolb, 2005; Kolb and Kolb, 2005b).

Table 7

Correlation of KLSI Raw Scores To Learning Type

Learning Style Dimension	**AC-CE Score**	**AE-RO Score**
Accomodating	<=7	>=7
Assimilating	>=7	<=7
Converging	>=7	>=7
Diverging	<=7	<=7

Results based on David and Alice Kolb's (2005b) revision of the KLSI (version 3.1), found that undergraduate science and math majors had an average AE-RO value of +5 and an AC-CE value of +12. A study conducted by Kolb (1984) based upon work conducted by Liam Hudson in 1966 on convergent and divergent learning styles, found that from a normative sample of 630 undergraduate majors, declared chemistry majors (n = 27) had an AE-RO value of ≈+3 and an AC-CE value of ≈+7 (see Figure 5). This places the sampled undergraduate chemistry majors just within the Assimilative domain.

Application. Although there is no guarantee that using a single instrument to determine an individual's learning style will be successful, the KLSI is based upon the *constructivist* approach to learning in which emphasis is placed upon "previous knowledge, beliefs, and experience" (Walker, 2002, p. 1). This approach was held in high regard by such esteemed educational theorists such as John Dewey and Jean Piaget (Lambert et al., 2002; Kolb & Kolb, 2005b). The KLSI holds true the precept that learning is a cycling process of constructing knowledge amongst the learning modalities by which a "learner touches all bases." These bases include the following: (a) experiencing, (b) reflecting, (c) thinking, and (d) acting in a recursive process that is responsive to the learning situation and what is being learned (Kolb & Kolb, 2005b, p. 2). Assimilating material in this manner forms links of knowledge which can be used in novel situations.

Threats to Validity and Reliability. Much of the criticism regarding the KLSI and its use as a viable psychometric device, mostly revolve around prior manifestations of the device in 1971 and in 1976. Some studies indicated a low correlation between learning style factors while others cited low test-retest reliability, mostly related to the low level of question sets (9) and corresponding answer choices. (Henke, 2001, Kolb & Kolb, 2005b). The cited concerns led to revisions in 1985, 1993, and in 1995. Noted modifications included: (a) adding items to the questioning set (totaling 12), (b) simplifying the wording used in the questions to a lower reading ability while changing some of the sentence stems, and (c) using a more diverse normative reference group. Internal reliability estimates remained high (overall) in these versions, with a marked increase in the test-retest reliability due to a random scoring format designed to dissuade individuals from determining the questioning patterns. The current version of the KLSI (version 3.1) includes a more diverse and representative sample of 6,977 individuals and a chart to covert the inventory scores (Kolb & Kolb, 2005b).

The New York Regents Exam (Physical Setting - Chemistry)

For the purposes of this research study, two parallel 30 question tests (one pretest and one posttest) were constructed to measure the level of conceptual development attained within the science subdiscipline of chemistry. Questions were taken from released (public domain) versions of the New York Regents exams (Physical Setting – Chemistry) obtained through the New York Department of Education's website (http://www.nysedregents.org/testing/scire/regentchem.html). This was due to the fact that (as of the fall of 2009), state level EOCT (science) testing in Georgia only consisted of biology and physical science, thus no test questions or prior released versions for chemistry existed. Selected problems for the two test versions were completely independent of those found in the course textbook – *Chemistry: Matter and Change* (2008), and self-produced by the instructor (except in the instance where a Georgia standard was not specifically addressed).

Construct validity was established through using previously vetted questions from the New York Regents exam and aligning them with the Georgia Chemistry Performance Standards (see Appendix J). The alignment of the pre- and posttest question numbers with the version (month/year), and New York Regents question number, with the Georgia Chemistry Performance Standards can be found in Appendixes D and F respectively. The corresponding tests (both pre- and post-) can be found in Appendixes C and E respectively. Table 8 below lists and describes the standards utilized during the evaluative term and their correlation to the chemistry concepts (Georgia Department of Education, 2009a).

Table 8

Georgia Chemistry GPS Standards and Curriculum Indicators

GPS Number /Subsection	**Content Description**	**Question Numbers**
SC1b	Identify substances based on chemical and physical properties.	6, 18
SC1c	Predict formulas for stable ionic compounds (binary and tertiary based on balance of charges.	10, 22
SC1d	Use IUPAC nomenclature for both chemical names and formulas: • Ionic compounds (Binary and tertiary) • Covalent compounds (Binary and tertiary) • Acidic compounds (Binary and tertiary)	2, 28
SC2a	Identify and balance the following types of chemical equations: • Synthesis • Decomposition • Single Replacement • Double Replacement • Combustion	7, 21
SC2b	Experimentally determine indicators of a chemical reaction specifically precipitation, gas evolution, water production, and changes in energy to the system.	11
SC2c	Apply concepts of the mole and Avogadro's number to conceptualize and calculate: • Empirical/molecular formulas, • Mass, moles and molecules relationships • Molar volumes of gasses.	14, 23
SC2d	Identify and solve different types of stoichiometry problems, specifically relating mass to moles and mass to mass.	15, 26
SC2e	Demonstrate the conceptual principle of limiting reactants.	17
SC2f	Explain the role of equilibrium in chemical reactions.	3
SC3a	Discriminate between the relative size, charge, and position of protons, neutrons, and electrons in the atom.	4, 20

SC3b	Use the orbital configuration of neutral atoms to explain its effect on the atom's chemical properties.	8
SC3c	Explain the relationship of the proton number to the element's identity.	12, 25
SC3d	Explain the relationship of isotopes to the relative abundance of atoms of a particular element.	14
SC3e	Compare and contrast types of chemical bonds (i.e., ionic, covalent).	13, 27
SC4a	Use the Periodic Table to predict periodic trends including atomic radii, ionic radii, ionization energy, and electronegativity of various elements.	5, 9, 24, 30
SC4b	Compare and contrast trends in the chemical and physical properties of elements and their placement on the Periodic Table.	1, 19, 29

The pre- and posttest questions were reviewed by two veteran chemistry teachers (see Appendixes G-H), including the county science curriculum coordinator. Both validated the questions on the test are representative of the foundations of the curriculum. In addition, the external validity for the exams were controlled through the use of Cronbach's alpha reliability test.

Analysis of Data

The purpose of this study was to test two hypotheses concerning the use of learning styles to measure the level of chemistry achievement at a local area high school approximately 35 miles southwest of Atlanta, Georgia. The first question the researcher attempted to answer was - Can modifying a high school chemistry curriculum to accentuate a student's learning preference affect a shift towards the Assimilative domain according to the Kolb Learning Style Inventory? The researcher divided the analysis into two groupings based upon Kolb's theory of learning and how knowledge results from the resolution of dialectics (i.e., learning mode scales).

The first grouping consisted of determining the significance of how individuals transform experience, or how we actually do things. This learning dimension results from resolving the difference between the Active Experimentation (AE) and the Reflective Observation (RO) learning styles (e.g., AE-RO) on the KLSI (see Figures 4 and 5). The second grouping consisted of determining the significance of how individuals grasp experience, or how we think about things. This learning dimension results from resolving the difference between the Abstract Conceptualization (AC) and the Concrete Experience (CE) learning styles (e.g., AC-CE) on the KLSI (see Figures 4 and 5). An independent samples *t*-test was performed, set at an alpha level of .05, to analyze the degree of significance of the shift in both AE-RO and AC-CE groupings.

A shift towards the Assimilative domain would assist in corroborating Hudson's findings (as found in Kolb, 1984, p.86), that this learning dimension does establish connections that fosters developmental growth in the chemical realm and thus affirms alternative hypothesis 1. A shift away from the Assimilative domain would support the null hypothesis for this proposition.

The second question the researcher attempted to answer was – Is there a correlation between the improvement in student learning based upon the students' preferred learning modality (as measured by the difference in pre- and posttest scores on a chemistry-concepts diagnostic) and a shift towards the Assimilative domain in the Kolb Learning Style Inventory? The initial component was to assess the level of improvement of the two chemistry exams by conducting an independent samples *t*-test ($\alpha = .05$). The second component was to compare the resultant gains in the exams against the proximate changes in the KLSI posttest administration based upon the two modes of transforming (AE-RO scale) and grasping experience (AC-CE) scale (see Figure 19). A correlation between 0.1 and .3 is indicative of a small correlation, while 0.3-0.5 and greater than .5 (> .5) are indicative of a medium and large correlation respectively. The sample data provided in Figure 19 shows a significant correlation (with a Pearson's *r* correlation of .71633) between the exam gains for the visual learning modality when plotted against the changes in the Kolb Learning Style administration.

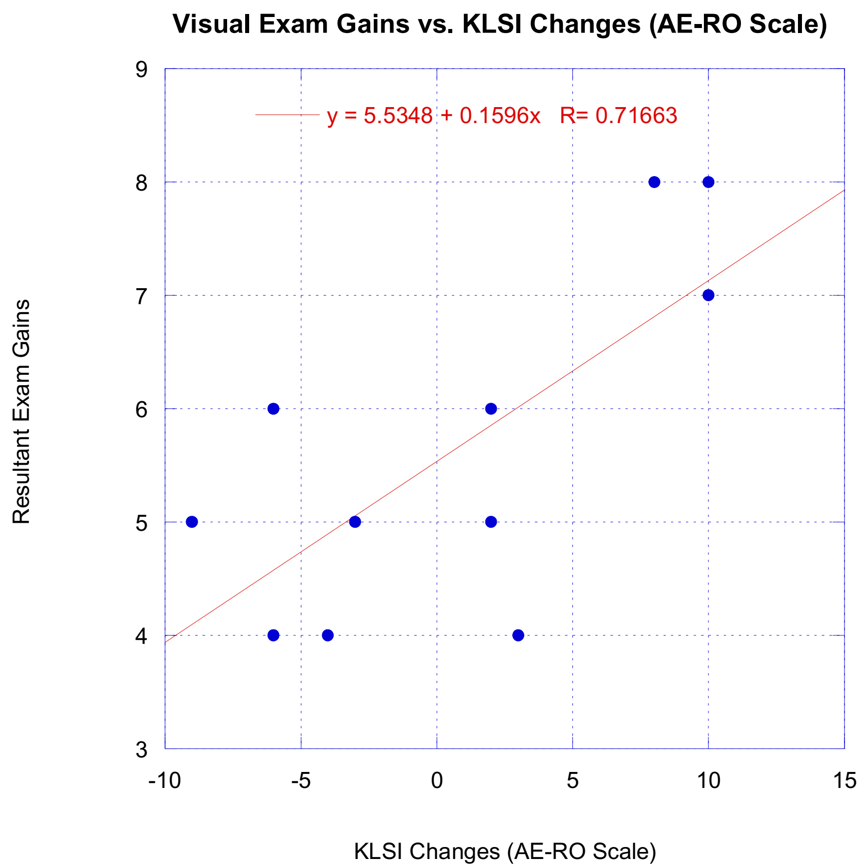


Figure 19. Sample resultant exam gains for the visual modality plotted against the proximate Kolb Learning Style changes on the AE-RO scale.

Treatment

The treatment utilized (in this pre-experimental one-group pretest-posttest design study) to categorize learners into cooperative learning groups, based upon their preferred learning modality, was the Learning Preference Checklist, or the VAK model. Regarding this issue, Samples (2000, p. 50) wrote that utilizing "instructional approaches that use learning modalities…[and]… learning styles… are viable approaches for creating science programs that are more realistically linked to larger social issues and the increasingly complex world." More so, they...

1. Nurture flexibility in thinking.
2. They reinforce the idea that there are many legitimate ways of acquiring and organizing knowledge and experience.
3. They foster and appreciation of the individual.
4. They enhance the likelihood of student success.

In addition, it is noted that "successful learners often function in more than one modality" (McKeown, 2003, p. 872). If students are encouraged to explore other modalities without threat or penalty, they can become stronger students (Samples, 2000; McKeown, 2003).

The process protocol for the seven week study initially included administering three assessments, each within a short time span. The Learning Preference Checklist (VAK) was issued to appraise the preferred learning modalities of the students to establish homologous cooperative learning groups (as best that can be arranged). The students were then given the Kolb Learning Style Inventory (KLSI) pretest and the Chemistry Concepts Pretest (see Appendixes C-D) in short succession to gauge the initial learning dimension of the students (see Figures 4-5) and establish a base level of knowledge to work from. The data obtained from the KSLI was utilized to modify the approach students took to solving problems of increased conceptual complexity and rigor. Based upon the data from the Chemistry Concepts Pretest, modified instruction was then directed towards GPS standards that had yet been mastered.

The curriculum was then be differentiated for each learning modality. Figure 20 below shows an example of how a key concept (molar mass) is applied and differentiated for a visually oriented learner. In this example, the key term is defined and underlined in yellow (a procedure held consistent through the course) and other essential components in the definition are highlighted in a different color (orange). Visual representations were scanned in from the periodic table of the elements while the procedure for calculating molar mass is shown in green.

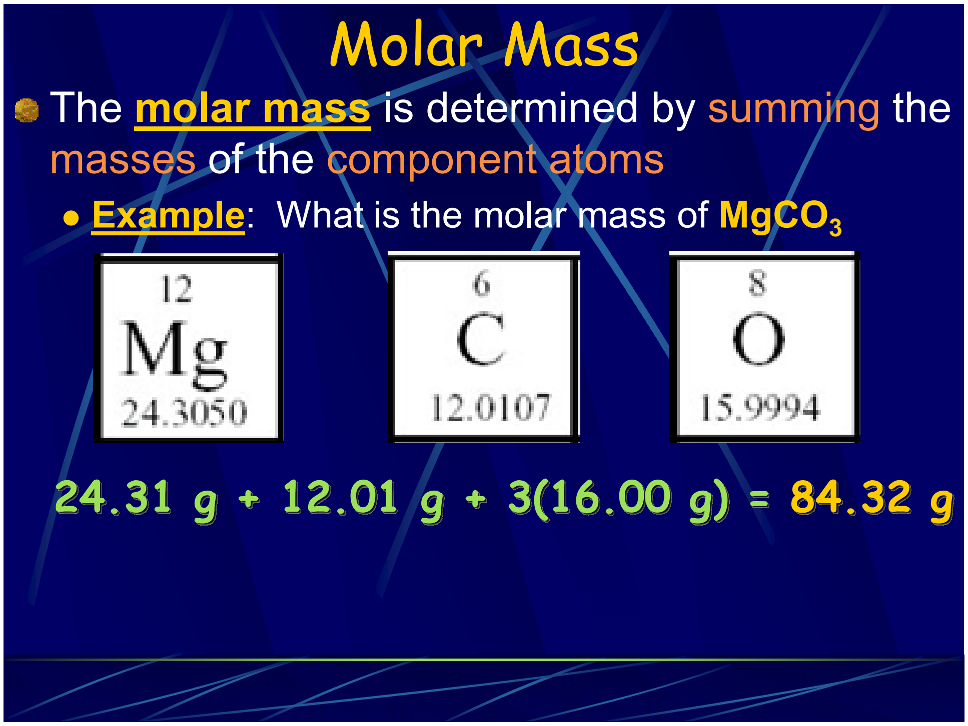


Figure 20. Chemistry notes regarding the application of a key chemistry concept (molar mass) differentiated by content for learners with a visual modality preference (from Byrnes, 2009a).

Students with an auditory preference benefited through the use of the verbal explanation of the notes by the instructor and through "student explained" examples (see Figure 21).

Student Explained Examples on Molar Mass

1. Determine the molar mass of the following compound: NaOH
   Answer: **40 g/mol**

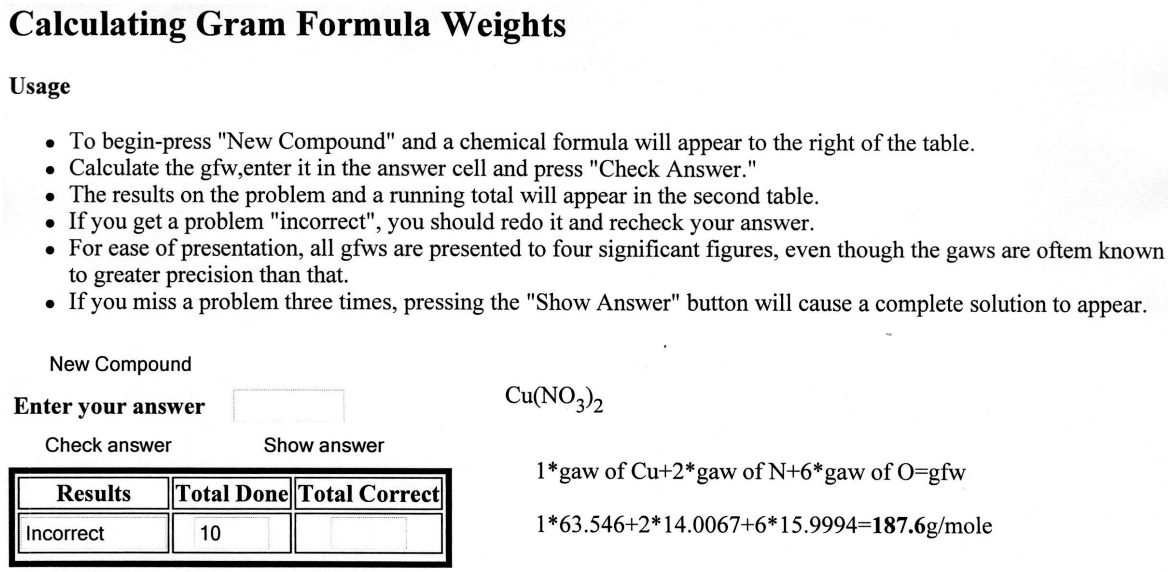
2. Determine the molar mass of the following compound: $Sr(NO_3)_2$
   Answer: **211.64 g/mol**

3. Determine the formula and molar mass of the following compound:
   Magnesium tripolyphosphate
   Answer: $Mg_5(P_3O_{10})_2$ **= 627.37 g/mol**

4. Determine the formula and molar mass of the following compound:
   Gallium ferrocyanide
   Answer: $Ga_4(Fe(CN)_6)_3$ **= 914.87 g/mol**

Figure 21. Student explained examples reviewing the application of the key term – molar mass – which benefit students with a verbal modality preference (from Byrnes, 2009a).

Figure 22 shows an example of a tutorial exercise regarding molar mass (also known as gram formula weight) which benefited all students, dependent of modal learning preference. These exercises not only provide immediate feedback, they also provide the solution to a problem if students are having difficulty applying the procedural aspects to the concept. In this specific example, students obtain a new problem by pressing the appropriate button. If the correct solution is entered, a new problem will be displayed. If an incorrect solution is given three times, the procedure, as well as the final solution, will be displayed.



Calculating Gram Formula Weights

Usage

- To begin-press "New Compound" and a chemical formula will appear to the right of the table.
- Calculate the gfw,enter it in the answer cell and press "Check Answer."
- The results on the problem and a running total will appear in the second table.
- If you get a problem "incorrect", you should redo it and recheck your answer.
- For ease of presentation, all gfws are presented to four significant figures, even though the gaws are oftem known to greater precision than that.
- If you miss a problem three times, pressing the "Show Answer" button will cause a complete solution to appear.

New Compound

Enter your answer

$Cu(NO_3)_2$

Check answer Show answer

Results	Total Done	Total Correct
Incorrect	10	

1*gaw of Cu+2*gaw of N+6*gaw of O=gfw

1*63.546+2*14.0067+6*15.9994=**187.6**g/mole

Figure 22. A molar mass review exercise which displays the chemical formula along with the procedure (broken down into segments) required to obtain the solution (from Byrnes, 2009b).

Bretz (2005), McKeown (2003), and Sprenger (2008) also made reference to adapting (a) curriculum/activities to accentuate learning for students with a kinesthetic modality preference. When working in this area, one of the primary principles to follow is to make an activity engaging while allowing freedom of movement. Figure 23 shows an example of such an exercise by which students in the classroom are divided into six groups and provided with a portable markerboard and dry-erase marker. The cooperative learning groups will in turn determine the formula and molar mass of the compound in question. Groups must also incorporate at least five key terms from prior units in their explanation. The justification behind this is to demonstrate the relationship between past and present work. Visual and auditory learners can both benefit from this type of activity. Assignments for Unit III (chemical composition), of which molar mass is a part, can be found in

Appendix G. All assignments, with the exception of the Essential Questions and Review, are offered as flexible scaffolding assignments and will be utilized as a Problem-Based Learning strategy on a "as needed" basis to assist students with developing skills to become better self-directed learners.

Take the **names** of the following **compounds** and determine the **formula** and **molar mass** of each. In addition to determining the type of compound (Type I, II, or III), use **5** of the following key terms in your explanation: anion, atom(s), atomic mass, atomic number, cation, compound, electron(s), element, family, ion, metal, metalloid, neutron(s), nonmetal, oxidation number, period, polyatomic ion, proton(s), subscript, superscript, valence electrons.

Group I:
1. Calcium phosphide
2. Iron (II) nitrate

Group II:
1. Gallium bromide
2. Disulfur trioxide

Group III:
1. Carbon tetrachloride
2. Copper (II) selenide

Group IV:
1. Iron (III) orthosilicate
2. Rubdium nitride

Group V:
1. Trinitrogen pentoxide
2. Strontium molybdate

Group VI:
1. Tin (IV) arsenide
2. Aluminum pyrophosphate

Figure 23. A cooperative learning exercise, revolving around determining the formula and molar mass of a compound, designed for students with a kinesthetic modality preference.

After the seven week evaluative period, the KLSI posttest and the Chemistry Concepts posttest were administered, also within short succession from one another. The students were directed (prior to the KLSI posttest) to specifically think about how they viewed approaching solving problems dealing with chemistry concepts in the present (with differentiated techniques) as compared to without.

Protection of Participants Rights

Many measures were taken by the researcher to protect the rights of the student participants. Initially, no data was collected until the permission of the Walden Institutional Review Board (IRB) was obtained (reference number 10-30-09-0350479). As confirmed by the IRB, the distribution of consent/assent forms was not necessary because of the incorporation of the research into the Local Area High School's professional development plan (PDP). Copies of all materials with student reference numbers are currently being stored in a secure location.

Researcher's Role

The principal investigator for this study was a science instructor with 15 years experience at the high school level who previously spearheaded the chemistry team's transition from an objective-based to the standards-based system known as the Georgia Performance Standards (GPS). The primary researcher also had further experience as a research assistant in the field of marine biology as well as serving as an adjunct instructor for a term at the community college level. In the context of this study, the researcher's role included teaching students in several subjects during the course of the study, one of which being chemistry, collecting data, and analyzing the results.

To control for investigative bias, a secondary researcher was chosen who holds the same view (as the principal investigator) of how students should approach and learn chemistry. As a teacher with over 25 years experience in the classroom, in addition to several years spent in private industry, this individual formerly served as a department head at the LAHS and has a strong working relationship with the primary researcher. Both teachers scheduled cooperative planning sessions throughout the course of the study in an attempt to remain consistent with the core principles of the study.

CHAPTER 4:

RESULTS

Introduction

This chapter presents the major findings of the study on *Assimilative Domain Proficiency and Performance in Chemistry Coursework*. The purpose of the preexperimental one-group pretest-posttest research investigation was to test two hypotheses concerning the use of learning styles to measure the level of chemistry achievement at a local area high school approximately 35 miles southwest of Atlanta, Georgia. Over a 7 week evaluative period, a randomized sampling population of 47 college-preparatory chemistry students took a classification diagnostic and a series of four pre- and posttest assessments to investigate the following questions and either accept or reject the following hypotheses:

Research Question 1

Can modifying high school chemistry curriculum to accentuate a student's learning preference affect a shift towards the Assimilative domain according to the Kolb Learning Style Inventory?

Null Hypothesis 1

Modifying a high school chemistry curriculum to accentuate a student's learning preference will not affect a significant shift towards the Assimilative domain according to the Kolb Learning Style Inventory.

Alternative Hypothesis 1

Modifying a high school chemistry curriculum to accentuate a students learning preference will affect a shift towards the Assimilative domain according to the Kolb Learning Style Inventory.

Research Question 2

Is there a correlation between the improvement in student learning (as measured by the difference in pre- and posttest scores on a chemistry-concepts diagnostic) and shift towards the Assimilative domain in the Kolb Learning Style Inventory?

Null Hypothesis 2

There is not a significant correlation between the improvement in student learning (as measured by the difference in pre- and posttest scores on a chemistry-concepts diagnostic) and shift towards the Assimilative domain in the Kolb Learning Style Inventory.

Alternative Hypothesis 2

There is a significant correlation between the improvement in student learning (as measured by the difference in pre- and posttest scores on a chemistry-concepts diagnostic) and shift towards the Assimilative domain in the Kolb Learning Style Inventory.

Research Tools and Procedures

The preliminary step in this research process was to administer the VAK (O'Brien, 1990), to determine each student's preferred learning modality (either visual, auditory, or kinesthetic). The intension of using a diagnostic tool such as the VAK was not to specifically type people (Learning and Teaching Scotland, 2005, p. 1), but to provide a means to differentiate curricular components and instructional methodologies to suit each student's perceived modal strength (Carbo & Hodges, 1988; Fleming, N.D, 1995; Fleming, N.D. & Baume, D., 2006; Fleming, N.D. & Mills, C., 1992, O'Brien, L., 1989). Average percentages and correlated standard deviations were calculated for each of the three groupings. Homogeneous modal groups (as best that can be arranged by the instructor) were then assembled for instructional purposes.

The ensuing day, the initial administration of the KLSI (Kolb, 2005) was given in conjunction with the chemistry concepts pretest. The KLSI itself is a self evaluative instrument consisting of 12 questions concerning different learning situations. Respondents were required to rank order sentence endings (from 4 – most like you; to 1 – least like you), which correlate Kolb's learning dimensions to learning styles. The scores for each of the learning style types – Accomodating, Assimilating, Converging, and Diverging – were determined by using a scoring grid provided by Version 3.1 of the KLSI (Kolb, 2005, p. 7) (see Figure 5). Table 7 shows the qualifying values for each learning style type.

The target value for the study is for students to transform their learning style to lie within Assimilative domain at the AE-RO points of $\approx$+3 and the AC-CE points of $\approx$+7. The determination of this goal point was based upon work conducted by Hudson in 1966 and was further studied and reported by Kolb (1984). The determination of an individual's learning dimension is crucial and will assist in establishing connections which will help link conceptual knowledge with prior experiences, which is a part of the main constructs of Kolb's ELT (Kolb, 1984).

Immediately following the initial administration of the KLSI, the chemistry concepts pretest was administered (Test A – see Appendix C). The 30 question multiple choice format pretest was constructed from released public domain questions from the New York Regents - Physical/Chemical Setting exam with each question being correlated to the Georgia Performance Standards (GPS) (see Appendix D). After a 7 week evaluative period, the final administration of the KLSI was given, again in conjunction with the chemistry concepts posttest (see Appendix E). Appendix F contains the answers and GPS standards comparison.

Points representing the average score of the KLSI pre- and postadministration were plotted on the Learning Style Type Grid supplied with Version 3.1 of the KLSI (Kolb, 2005, p. 7) against the optimal goal point for undergraduate chemistry majors (Kolb, 1984). Shading was also added to show the standard deviation associated with the measurements. In addition, a paired samples *t* test was performed, set an alpha level of .05, to analyze the degree of significance of the shift in the both the modes of transforming (AE-RO scale) and grasping experience (AC-CE scale). To further correlate these variables, a Pearson's *r* analysis was completed for each of the aforementioned scales and graphed against the students' preferred learning modality to determine the level of significance of the resultant transformations.

A postfactor analysis showed that the chemistry concepts pre- and posttest assessments had a Cronbach's alpha reliability coefficient of .451. Additional analyses of the pair of concepts exams included a paired samples *t* test (set at an alpha level of .05). A table was also created displaying each of Kolb's Learning Domains against the qualifying number of students in said domain after each of the KLSI pre and posttest administrations. The chemistry average concepts pre- and posttest exam scores are also displayed and correlated to each of the learning domains. The raw data for the research is available from the researcher by special request.

Data Analysis

A total of 42 students (sample size $n = 42$) completed all facets of the research study from a sample population of 47 students. According to the calculator provided by Creative Research Systems (2009), a sample size of 42 students meets the minimum criteria to obtain a 95% confidence interval with a 5% chance of error. Figure 24 shows the breakdown of each student's preferred learning modality according to average percentage and the number of students sampled. The breakdown shows that the students had an average visual modality breakdown of 33.8% ($n = 17$ students), an auditory average of 32.1% ($n = 9$ students), and a kinesthetic average of 34.1% ($n = 16$ students).

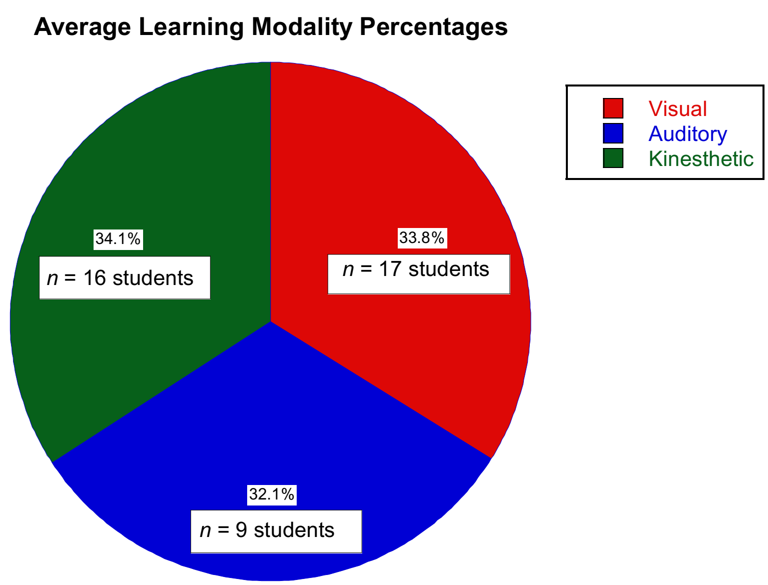


Figure 24. Pie graph displaying the average learning modality percentages according to Lynn O'Brien's Learning Preference Checklist (VAK).

Figure 25 below displays the same information as the pie graph provided in Figure 24, yet with included error bars displaying the standard deviation for each of the learning modality preferences. Both figures show a close relationship amongst these variables.

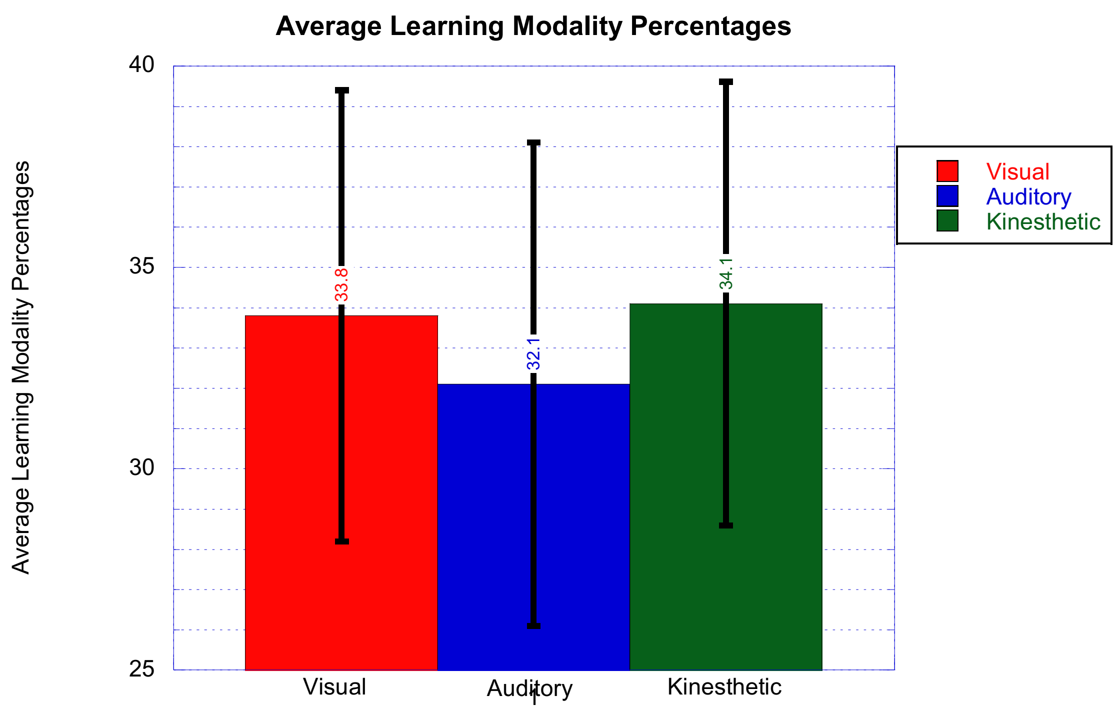


Figure 25. Bar graph displaying the Average Learning Modality Percentages with included Y-error bars.

The initial administration of the KLSI (*n* = 42) showed that students had an average AE-RO value of +4.3 and an average AC-CE value of +5.9. This places the average learning dimension of the tested students just within the Divergent quadrant (see Figure 26). The second administration of the KLSI showed an average AE-RO value of +2.3 and an AC-CE value of +3.9, again lying within the Diverging dimension. Based upon this data alone (and the differentiated curricular aspects offered by the instructor) the progression was away from the intended target goal and the Assimilative domain.

Figure 26 (see Appendix M for author's publication permission) displays the average scores of the KLSI pretest (purple circle) and posttest (green circle) administration plotted in relation to the intended target goal (red star). The standard deviations of the KLSI pre- and posttests are represented by the pink and yellow highlighted areas respectively. The orange (overlapping) area represents the commonalities between both administrations.

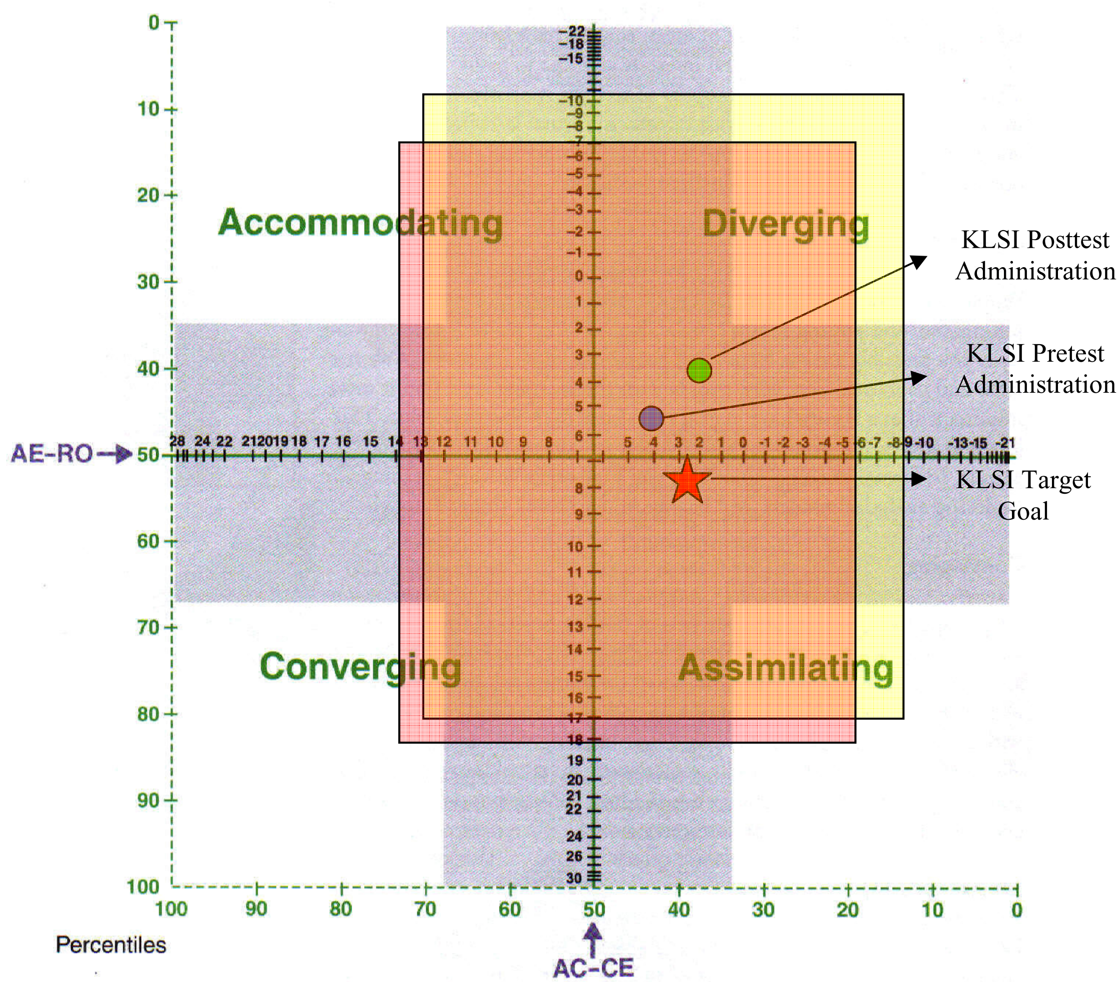


Figure 26. Values for the KLSI pre- and posttest administrations plotted against the KLSI target goal. Adapted with permission from the author (Kolb, 2005, p. 7).

The data from the two KLSI administrations is summarized in Table 9:

Table 9

KLSI Pre- and Posttest Data

Learning Scale	**Pretest Average Value**	**Pretest Deviation**	**Posttest Average Value**	**Posttest Deviation**
AE-RO	+4.3	± 9.8	+2.3	±10.8
AC-CE	+5.9	±12.2	+3.9	±13.4

A *t* test analysis showed the transforming dialectic (AE-RO) was not significant, $t(41) = 1.058$, $p = .296$, while the analysis for the grasping dialectic (AC-CE) showed nearly the same result, $t(41) = 1.054$, $p = .298$. Table 10 summarizes the results. Based on these results, null hypothesis 1 - Modifying a high school chemistry curriculum to accentuate a student's learning preference will not affect a significant shift towards the Assimilative domain according to the Kolb Learning Style Inventory - cannot be rejected.

Table 10

KLSI Learning Style Dialectic Resolution Significance (Sample Size n = 42)

Scale	**Dialectic Resolution**	**t Value**	***p* value**	**Significance @ α = .05**
AE-RO	Transforming	1.058	.296	No
AC-CE	Grasping	1.054	.298	No

A Pearson's *r* correlation was further conducted by which the KLSI (dialectic) scales were plotted against the resultant gains for each of the measured learning modalities. The results show primarily small correlations for the visual and kinesthetic modalities and medium correlations for the auditory modality. Students with a preferred visual preference had an AE-RO *r* value of .12897 and an AC-CE *r* value of .28165. Both scales showed a small correlation with the difference in pre- and posttest chemistry concept exam scores. The graphs for each of the values are respectively shown in Figures 27 and 28.

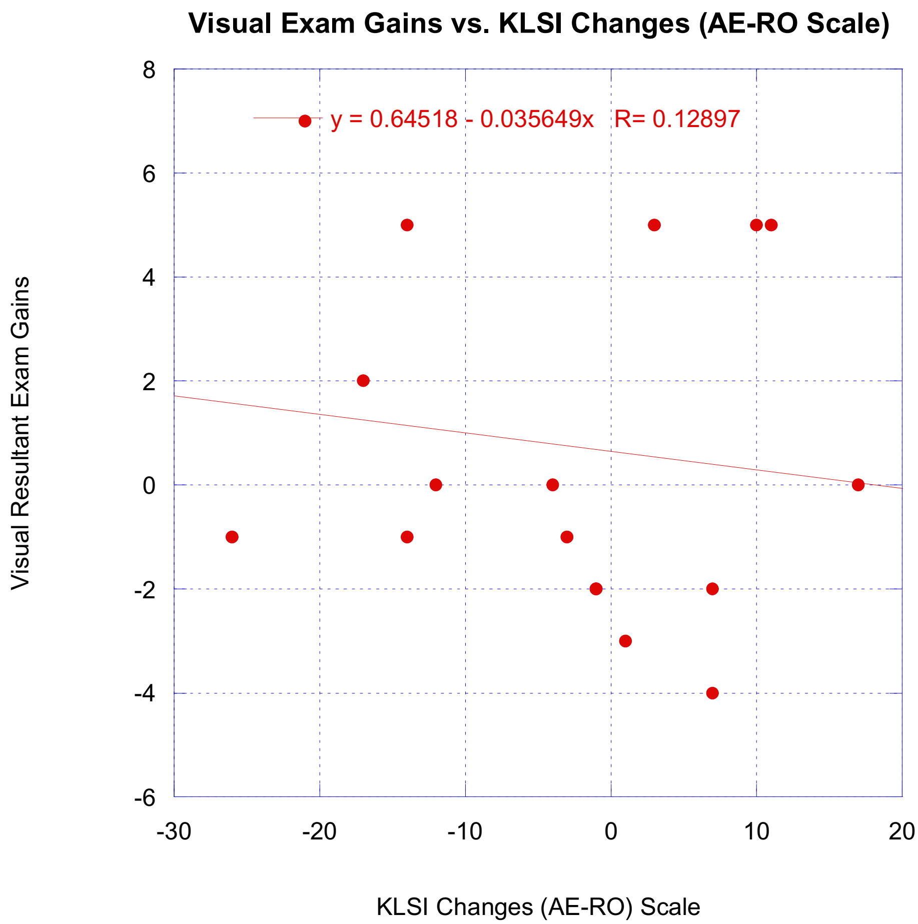


Figure 27. A Pearson's *r* correlation graph representing the KLSI changes on the AE-RO scale plotted against the resultant gains on a chemistry concepts exam for students with a preferred visual learning modality.

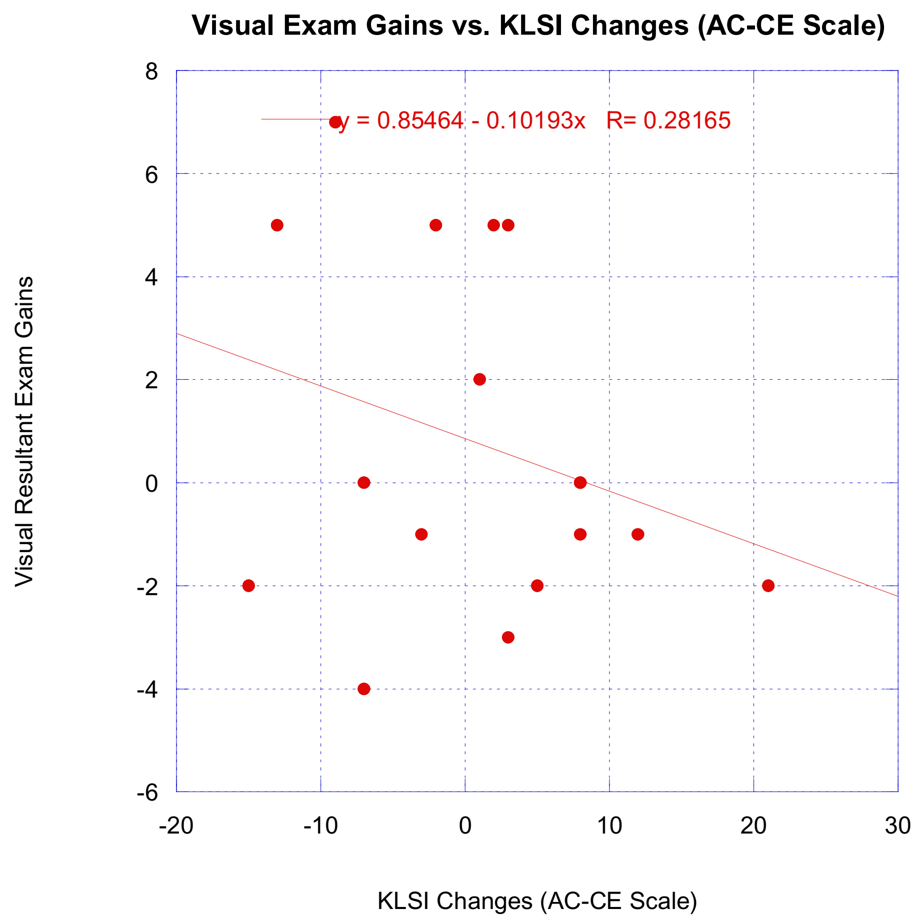


Figure 28. A Pearson's *r* correlation graph representing the KLSI changes on the AC-CE scale plotted against the resultant gains on a chemistry concepts exam for students with a preferred visual learning modality.

Students with an auditory learning preference posted the most significant correlation amongst the three primary learning modalities. Here, students had an AE-RO *r* value of .33789 and an AC-CE *r* value of .42538. Both scales showed a medium correlation with the difference in pre- and posttest exam scores, with the scale representing the grasping knowledge dialectic (AC-CE) bordering on a significant correlation. The graphs for each of these values representing the auditory modality are shown in Figures 29 and 30.

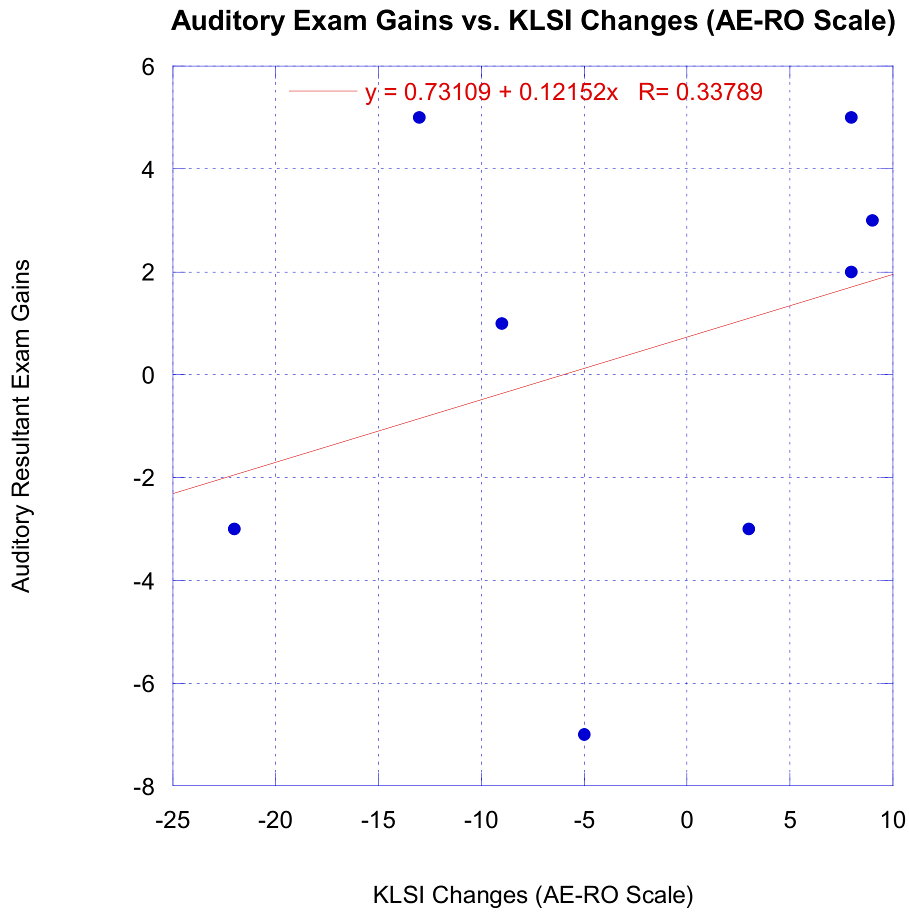


Figure 29. A Pearson's *r* correlation graph representing the KLSI changes on the AE-RO scale plotted against the resultant gains on a chemistry concepts exam for students with a preferred auditory learning modality.

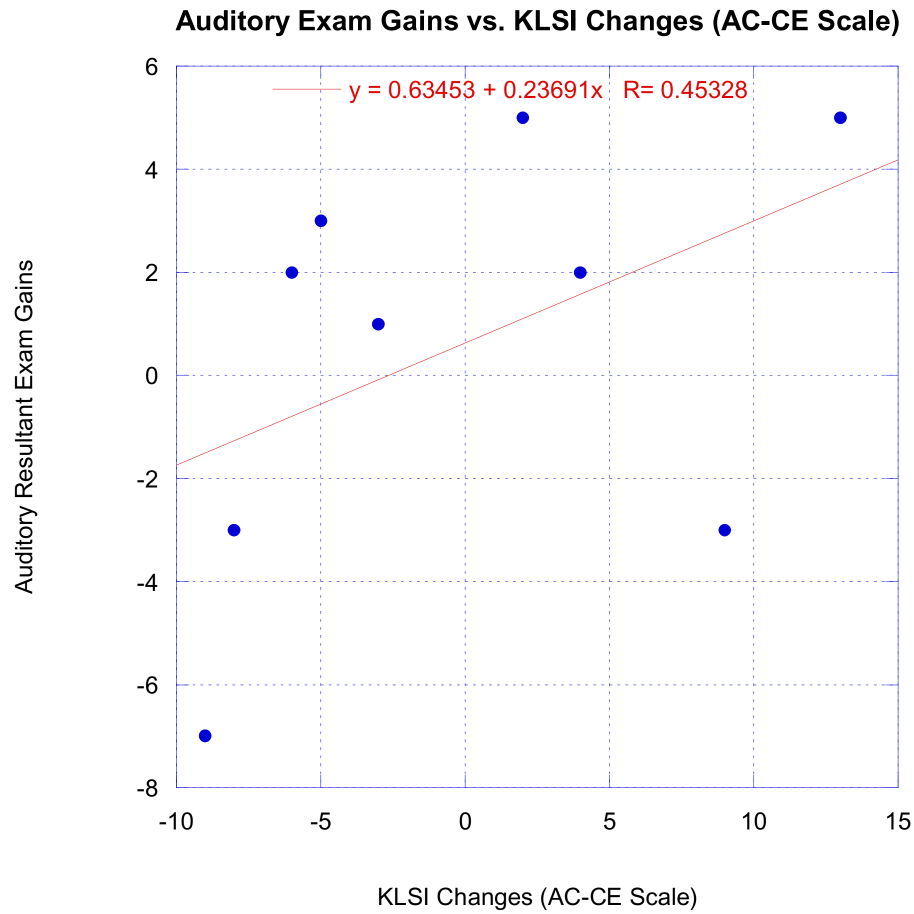


Figure 30. A Pearson's *r* correlation graph representing the KLSI changes on the AC-CE scale plotted against the resultant gains on a chemistry concepts exam for students with a preferred auditory learning modality.

Students with a kinesthetic learning preference posted (overall) the smallest levels of correlation as compared to the visual and auditory modalities. Students had an AE-RO *r* value of .22808 and an AC-CE *r* value of .03552. The correlation representing transforming experience (AE-RO) was small while the correlation representing grasping experience (AC-CE) was not significant, as it fell below the .1 level criteria. The graphs for each of these values representing the kinesthetic modality are shown in Figures 31 and 32.

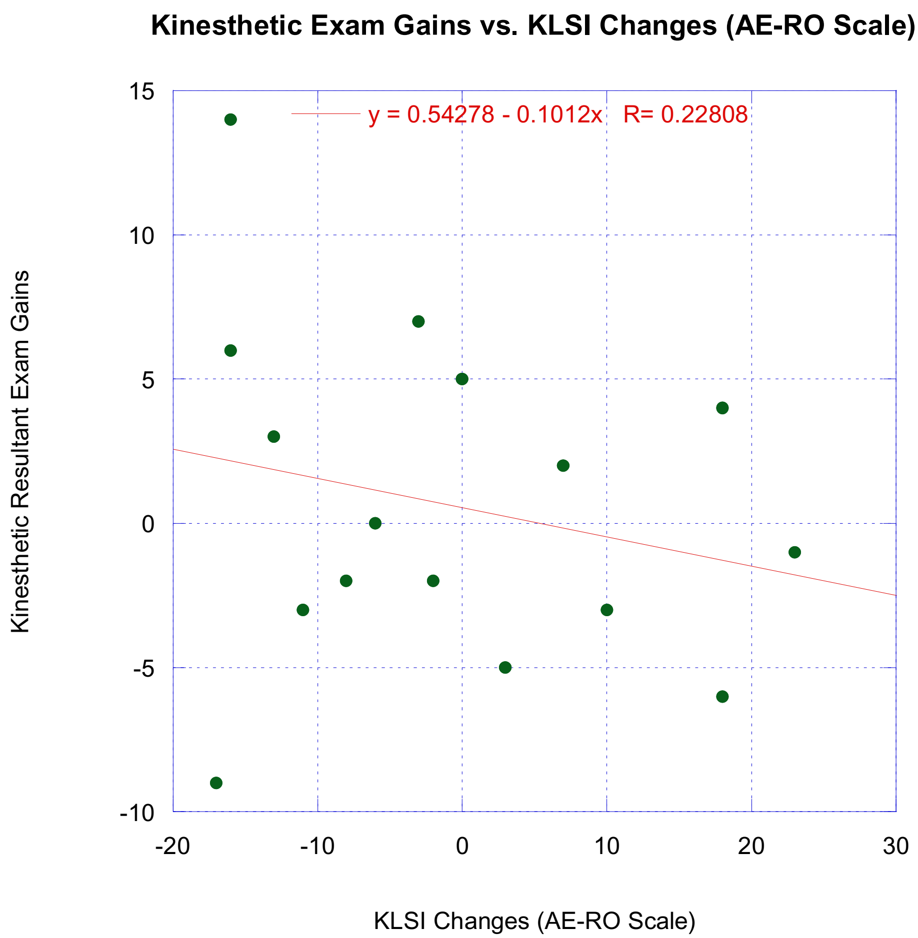


Figure 31. A Pearson's *r* correlation graph representing the KLSI changes on the AE-RO scale plotted against the resultant gains on a chemistry concepts exam for students with a preferred kinesthetic learning modality.

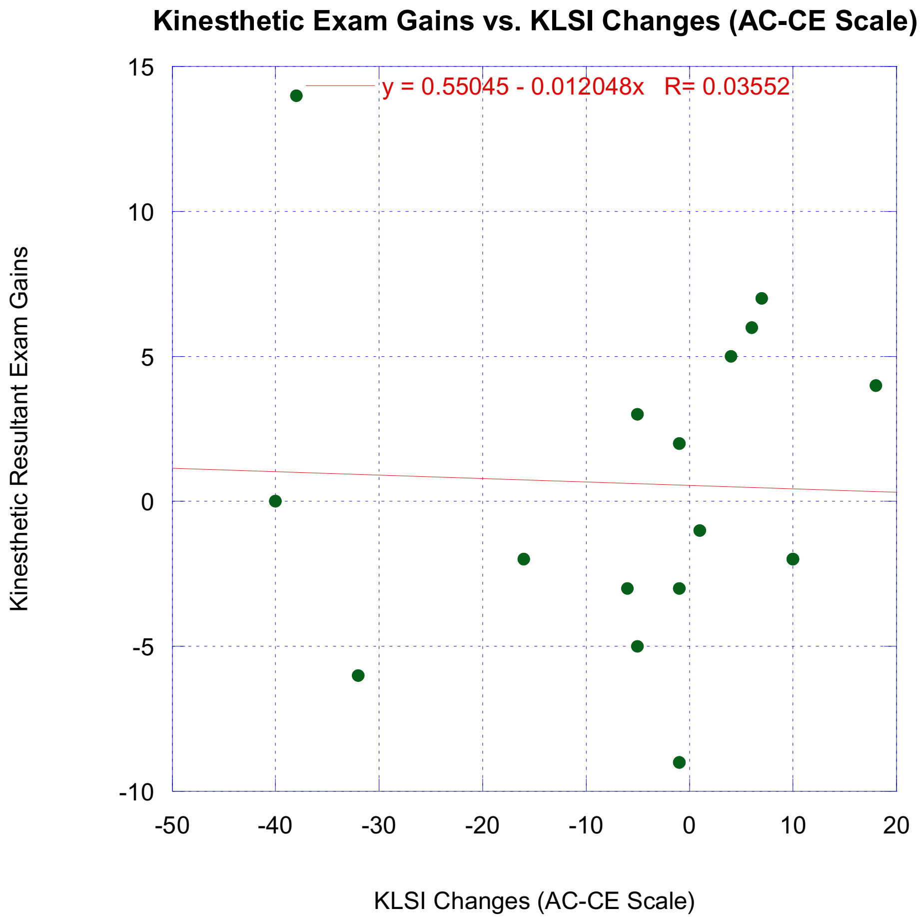


Figure 32. A Pearson's *r* correlation graph representing the KLSI changes on the AC-CE scale plotted against the resultant gains on a chemistry concepts exam for students with a preferred kinesthetic learning modality.

Table 11 summarizes the Pearson's *r* correlation data.

Table 11

Pearson's r Correlation Grouped According to Learning Modality.

Learning Modality	**AE-RO Pearson's *r***	**AE-RO Correlation**	**AC-CE Pearson's r**	**AC-CE Correlation**
Visual	.12897	Small	.28165	Small
Auditory	.33789	Medium	.42538	Medium
Kinesthetic	.22808	Small	.03552	N/A

The researcher also conducted a paired samples *t* test of the chemistry concepts pre- and posttest exams scores to determine if the associated change was significant. The results showed that the difference was not significant at the α=.05 level, $t(41) = -.619$, $p = .539$. Therefore null hypothesis 2 - There is not a significant correlation between the improvement in student learning (as measured by the difference in pre- and posttest scores on a chemistry-concepts diagnostic) and shift towards the Assimilative domain in the Kolb Learning Style Inventory – can also not be rejected.

A table (see Table 12) was also created further utilizing the collected data which shows the qualifying number of students in each o Kolb's Learning Dimensions (after each of the two administrations) compared against the average scores on the two concept test administrations for said dimension. One dimension (Accommodating) showed a sharp decrease in the number of students (7) after the posttest, while a second dimension (Converging) showed no increase at all (6 students). Two dimensions (Assimilating and Diverging) showed an increase in the number of qualifying students after the posttest. The increase for each grouping was by 1 student and 6 students respectfully.

The learning dimensions which showed a decrease or no change in the number of qualifying students also showed a dramatic decrease in the average chemistry concept test scores as compared from the pretest to the posttest administration. The Accommodating dimension showed an average decrease of 1.3 points (from 13.0 to 11.7), while the Converging dimension showed a similar decline of 1.5 points (from 13.0 to 11.5). The two dimensions which showed an increase in the number of students also saw the average chemistry concept exam scores rise. The Diverging dimension showed an average gain of 2.3 points (from 11.1 to 13.4) while the target Assimilative domain showed an average gain of 1.0 points (from 13.2 to 14.2), but also displayed the highest overall average of the four (14.2 points).

Table 12

KLSI Learning Dimension Changes.

Learning Dimension	**KLSI Pretest Number of Students**	**Concepts Pretest Average Scores**	**KLSI Posttest Number of Students**	**Concepts Posttest Average Scores**
Accommodating	14	13.0	7	11.7
Assimilating	14	13.2	15	14.2
Converging	6	13.0	6	11.5
Diverging	8	11.1	14	13.4

The only observed inconsistency within the analyzed data set was the Cronbach's alpha reliability coefficient for the chemistry pre- and posttest assessments. In this instance, a value of .451 was obtained. According to a series of online statistic notes obtained from North Carolina State University (2010), a lenient cut-off for such a value would be .60, thus indicating the results were not internally consistent. Despite the results of the analysis, the questions on the assessments themselves were correlated to the Georgia GPS Chemistry standards and peer reviewed by two highly qualified independent parties for relevance.

Summary

The purpose of this research study was to test whether differentiating a chemistry curriculum to accentuate an individual's modal learning preference can dually affect a shift towards the Assimilative domain according to the Kolb Learning Style Inventory and produce a significant difference in scores on a chemistry concepts exam, based on a pre- and posttest analysis. After the administration of O'Brien's (1990) Learning Preference Checklist (VAK), it was found that 17, 9, and 16 students had a visual, auditory, and a kinesthetic modal preference respectfully. The average percentages for all three modal learning preferences were all within ± 2% from each other, thus indicating a large cross section of students with an increased aptitude to adapt to multiple differentiated techniques.

A comparison of the KLSI pre- and posttest scores showed a shift away from the Assimilative domain, thus providing documentation as to not reject null hypothesis 1.
A *t* test comparison on a pair of chemistry concepts exams also did not produce a significant change, again providing ample evidence so as not to reject null hypothesis 2.
Section 5 presents a synopsis of the entire body of research including interpretation of the data, conclusions, and recommendations for future research. A brief summation and critical analysis is included that will explain the roles and responsibilities of the administration, the department, and the teachers, as well as a proposed course of action to address deficient test scores.

CHAPTER 5:

SUMMARY, RECOMMENDATIONS, AND CONCLUSION

Overview

This study focused on the specific use of learning styles to measure the level of chemistry achievement and whether the associated use of David Kolb's Learning Style Inventory (KLSI) (Kolb, 2005) is an accurate barometer of academic progression in the realm of high school chemistry. Within the research, two questions were answered: 1) Can modifying a high school chemistry curriculum to accentuate a student's learning preference affect a shift towards the Assimilative domain according to the Kolb Learning Style Inventory? 2) Is there a correlation between the improvement in student learning (as measured by the difference in pre- and posttest scores on a chemistry-concepts diagnostic) and shift towards the Assimilative domain in the Kolb Learning Style Inventory? The findings of the study showed that the students with a visual and kinesthetic modal learning preference were close in population (17 and 16 students respectively) while students with an auditory preference had approximately half the number of grouped individuals (n = 9). Despite the disparity in one grouping, the average percentages were all within ±2% from each other, indicating no highly distinguishable preference for any self-classified modal learning group (see Figures 24 and 25).

The learning dimension (as noted by David Kolb) was just within the Divergent quadrant after the initial administration of the KLSI. After the concluding administration of the KLSI, the progression of learning was away from the Assimilative domain and further evolved into the Divergent quadrant (see Figure 26). t test post-factor analyses showed a non-significant shift in each of the two dialectics (AE-RO → $t(41) = 1.058$, $p = .296$ and AC-CE → $t(41) = 1.054$, $p = .298$), thus validating the null hypothesis for research question 1: Modifying a high school chemistry curriculum to accentuate a student's learning preference will not affect a significant shift towards the Assimilative domain according to the Kolb Learning Style Inventory. An additional post factor *t* test analysis also showed the difference in a pair of chemistry concepts exams also failed to yield a significant difference at the α=.05 level ($t(41) = -.619$, $p = .539$)). This result validates null hypothesis 2: There is not a significant correlation between the improvement in student learning (as measured by the difference in pre- and posttest scores on a chemistry-concepts diagnostic) and shift towards the Assimilative domain in the Kolb Learning Style Inventory. A supplementary breakdown, however, did show a slight increase in the number of students progressing into the Assimilative domain. Qualifying representatives also possessed the highest average score after the chemistry concepts posttest administration (see Table 12).

Interpretation of Findings

Of the published literature that offers insights and explanations regarding instructional strategies, little, if any exists which directly emphasizes methodologies to monitor the level of conceptual development attained in a standards-driven science classroom. It is evident that it is not enough to wait until (nearly) the end of the school year and or evaluative term to enact changes necessary to promote these changes. A more proactive approach needs to be developed to reach the needs of individual students rather than a predominately reactive philosophy. Local area testing scores help to support this point.

The LAHS has only seen modest (short term) improvement in this area since the employment of the GPS curriculum in 2005, as measured (most recently in 2008) by the ACT-SRP (see Figure 33) (Governor's Office of Student Achievement, 2009c; 2007a). There have also been some modest gains in the percentage of students passing Georgia state tests, such as the EOCT and the GHSGT (see Figure 34) (Governor's Office of Student Achievement, 2009d-e; 2007c-d), however it has been reported that the most recent data for the 2008-2009 academic school year has shown an increase in the failure rate on the GHSGT to near 2006-2007 academic school year levels (around 15%). The pass-fail rate on the GHSGT is a preliminary indicator of an individual school's AYP status.

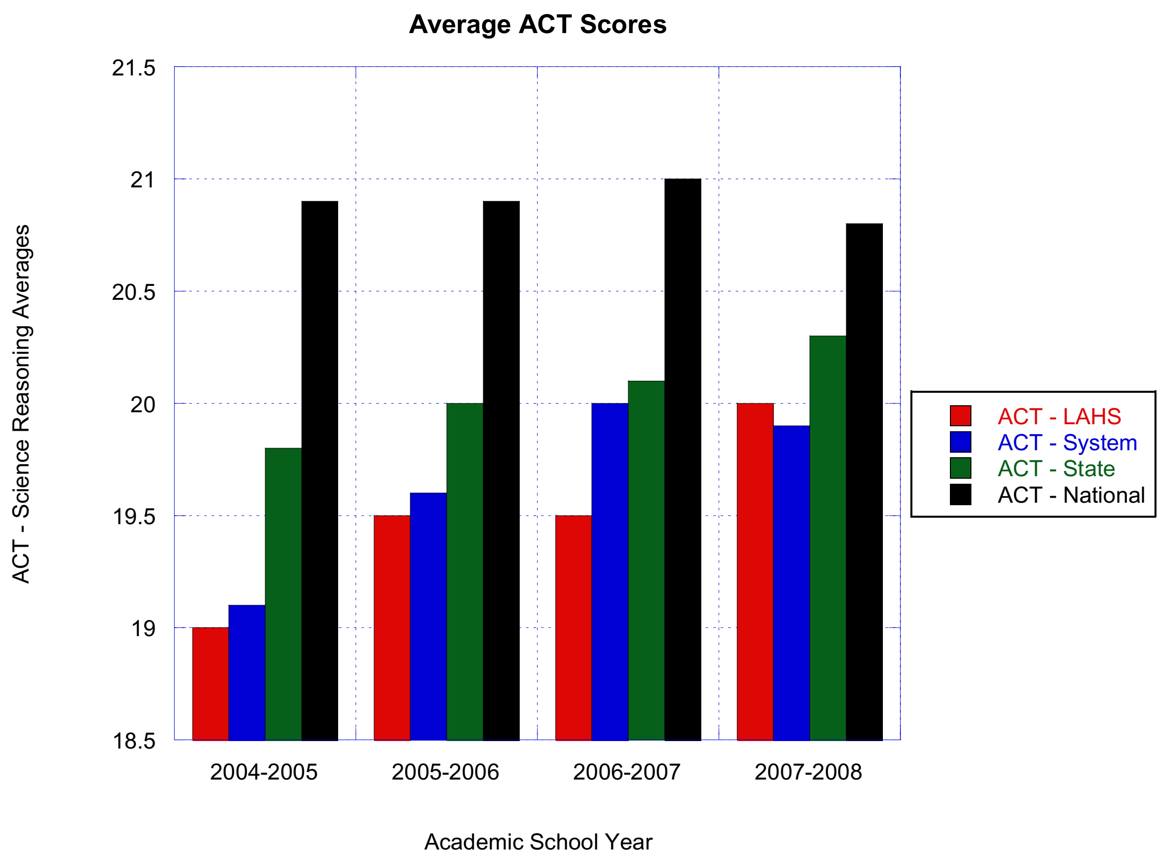


Figure 33. LAHS average ACT (composite and subtest) scores for academic years 2004/2005–2007/2008.

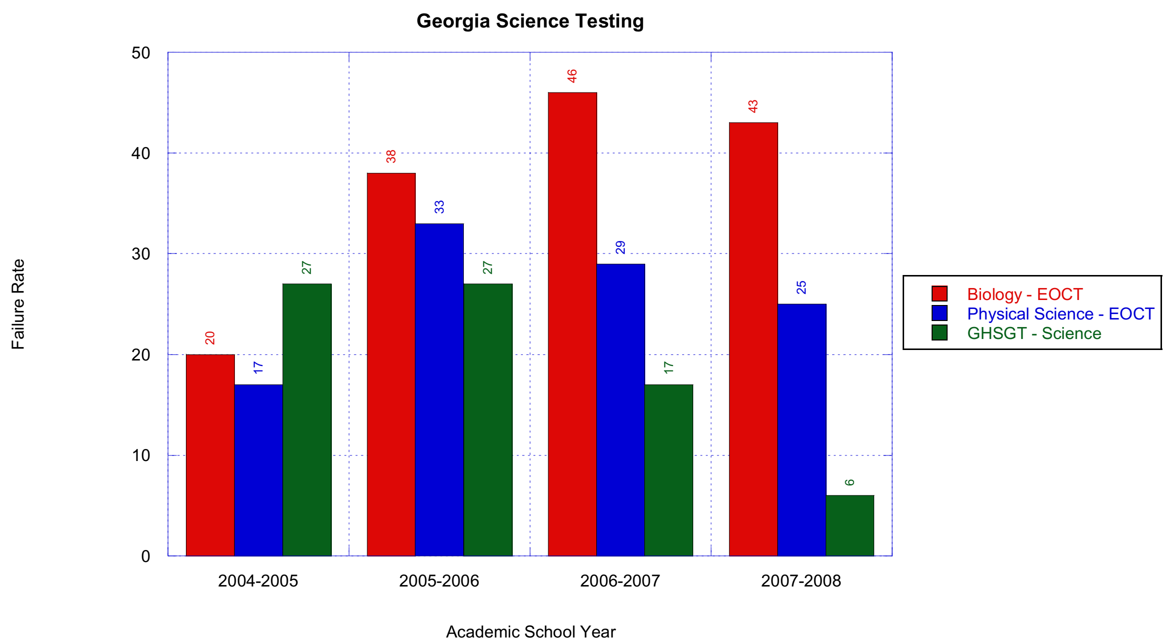


Figure 34. LAHS failure rates on state of Georgia science tests for academic years 2004/2005–2007/2008.

The use of the VAK was employed to more genuinely "engage student's of different learning styles" (McKeown, 2003, p. 872) and gain insights into how students process information (Samples, 2000). The incorporated use of an experiential pedagogy can also permit higher levels of cognitive development (Peterson, 2007). The use of the VAK also is well supported on the foundations of Kolb's Experiential Learning Theory (ELT) in Propositions 1, 3, and 4 (Brennan, 2005; Kolb & Kolb, 2005, p. 2):

<u>Proposition 1</u> - To enhance the process of learning, students should be actively engaged in a process which best accentuates their preferred learning modality.

Proposition 3 - The process of experiential learning revolves around resolving dialectics (transforming and grasping experience) within opposing regions of the cerebral cortex of the brain – from modes of watching and doing and feeling and thinking.

Proposition 4 - Learning should be thought of and approached as an integrated process relating to how an individual…perceives…in accordance to real-world situations.

The VAK, as with the rest of the components of this study, was not administered at the beginning of the intended evaluative term. A reasonable assertion can be made that the results are a product of the exposure to certain chemistry components rather than a true "unbiased" self-assessment. The small difference between each of the resulting percentages of each of the learning modality classifications (33.8% visual, 32.1% auditory, and 34.1% kinesthetic) (see Figures 24 and 25) provides a channel to overlap many tasks differentiated by content and process. This data also supports the proposition made by McKeown (2003), in that learners can function effectively in more than one modality. More so, individuals can supplement their understanding by being exposed to material when presented in alternate forms. In retrospect this may have been the wrong assumption to make.

As with the VAK, the initial administration of the KLSI was not completed at the beginning of the intended evaluative term. The students had already been preexposed to some of the differentiated instructional techniques designed to promote conceptual development in each learning modality. Thus, a reasonable assertion can be made that the outset of the initial administration of the KLSI showed values with a greater progression, when compared against Kolb's Learning Style Grid, than there would have been if the instrument had been delivered to the students at the beginning of the intended evaluative term. The dialectic value for transforming experience (AE-RO) was +4.3 and the dialectic value for grasping experience (AC-CE) was +5.9, placing the starting learning dimension just within the Divergent quadrant (within close proximity to the intended goal target in the Assimilative domain) (see Figure 26).

The second administration of the KLSI showed a progression away from the Assimilative domain and displayed an average overall AE-RO value of +2.3 and an AC-CE value of +3.9, again within the Divergent quadrant. *t* test analyses showed that the difference in scores between the pre- and post- administration of the KLSI were not significant at the $\alpha = .05$ level. Overall, the results for the transforming dialectic (AE-RO) was $t(41) = 1.058$, $p = .296$, while the analysis for the grasping dialectic (AC-CE) showed nearly the same result, $t(41) = 1.054$, $p = .298$. Due to the presented data, null hypothesis 1: Modifying a high school chemistry curriculum to accentuate a student's learning preference will not affect a significant shift towards the Assimilative domain according to the Kolb Learning Style Inventory – cannot be rejected.

If the results of the *t* test analyses are an affirmation of true developmental progression, according to Zieber (2009), the strategies utilized which appear to have benefited Divergers (in the specific case of chemistry) include the following (p. 4):

- Provide concrete examples
- Encourage students to consider the "why?" of a situation
- Include lecture and focus on specifics

Rather, the focus should have relied more heavily upon…

- Encouraging students to create theoretical models
- Use the lecture method, followed by demonstration
- Provide answers to problems
- Provide quantitative data for students to analyze

To further relate the effect learning styles have on the level of conceptual development in chemistry, a series of Pearson's *r* correlations were conducted by which the KLSI dialectic scales were plotted against the resultant gains in chemistry concept test scores. The results show primarily small correlations for the visual and kinesthetic modalities and medium correlations for the auditory modality (see Table 10 for a summary of the results).

The higher correlations for the primarily auditory learners are in line with Zieber's (2009) aforementioned strategies which positively affect Divergers and Assimilators in which there is the initial reliance upon a lecture means to either initially create or integrate personal experiences. According to Prince and Felder (2006, p. 7) and Armstrong and Parsa-Parsi (2005, pp. 682-684), this satisfies the first two issues/questions (Why? and What?) which must be delivered in order to successfully progress through Kolb's Experiential Learning Cycle and into a dimension which the approach is more in tune with producing successful results. With this methodology, there is less of a reliance on the visual aspect and even slightly less with the kinesthetic approach, thus the value fall in line with the curricular frameworks for designing a chemistry curriculum. Retrospectively, these results can be used as a tool for improvement. In order to make the results of dialectic transformations more indicative of true learning, curricular materials should have been differentiated further to promote a greater emphasis on the visual means and even more on the kinesthetic means.

The paired samples *t* test on the pair of chemistry concept exams also failed to produce significant results at the α=.05 level ($t(41) = -.619$, $p = .539$). Due to the presented data, null hypothesis 2: There is not a significant correlation between the improvement in student learning (as measured by the difference in pre- and posttest scores on a chemistry-concepts diagnostic) and shift towards the Assimilative domain in the Kolb Learning Style Inventory – cannot be rejected. A reasonable assertion can be made that the acceptance of the null hypothesis for research question 2 is directly related to the fact that the initial execution of the chemistry concepts pretest was not completed at the beginning of the intended evaluative term. The Local Area School System Curriculum Map for Chemistry (see Appendix B) had been altered by the instructor in order to accommodate the needs of the study.

The units planned for the pre- and posttests reviewed the main concepts presented in units focusing on The Atom and Patterns and Reactions. The instructor, with one exception (Measurement), initially focused on units examining Relationships (States of Matter, Gasses, and Solutions) and Equilibrium. Some preexposure could not be avoided. As stated in the Curriculum Map for Chemistry itself "units are written to be stand alone units that may be taught in any sequence" (Coweta County School System Intranet (2009, p. 1)).

In addition, one of the points of emphasis of the study was that the problems selected for two chemistry concept test versions were completely independent of those found in the course textbook and those self-produced by the instructor and or principal investigator. Language plays an important role in the learning process. If the language in the presented examples was significantly different from what was practiced, a greater emphasis is placed on converging rather than applying and synthesizing knowledge.

Even though both research questions failed to reject the null hypotheses, a postfactor analysis showed that there was an overall shift in the learning cycle towards the intended (Assimilating) domain as far as pure numbers are concerned (see Table 12). The two domains which appear earlier in the evolution of learning cycle (see Figure 4) (Converging and Accommodating) saw their numbers significantly decrease or remain stagnant. Likewise, the average scores also saw a decrease in overall average after the posttest analysis. This data supports the precept that developmental progression should produce an overall increase in scores.

The two domains which appear later in the evolution of learning cycle (see Figure 4) (Diverging and Assimilating), saw their overall numbers increase along with the average scores after the posttest analysis. The Diverging quadrant had the largest increase in students (6) and also produced the largest overall gains on the pair of the chemistry tests. However, students progressing into the intended target domain (Assimilating) posses the overall test average. Thus a reasonable assertion can be made that progression into Assimilating domain will produce a higher level of conceptual understanding in the chemical realm.

The results of this study do provide insights regarding the adjustments which can be made to facilitate students' Assimilative domain proficiency. Foremost is the method of evaluation. The learning processes were all experienced through multiple modalities, while the conceptual assessments had a strong verbal-linguistic component, in addition to being multiple-choice in format. To obtain an understanding of the level of conceptual development, the evaluative method should reflect the method used in practice. In addition, when provided the opportunity to experience learning in other modal areas, students should be allowed to switch groupings to accommodate their developed preferences rather than being affixed to a single modal grouping.

Should said recommendations be set forth, a valid assertion can be made that learning styles can affect an individual's approach to learning. The practical applications of which can be utilized to help student's process knowledge, which can be applicable in novel situations. For example, increasing the chances of an individual to pass and or excel on state-mandated tests, in addition to leading individuals to a career choice which matches their ability to process the information.

Implications for Social Change

Despite the official findings found in this individual research piece, based upon pure numbers (see Table 12) and the volume of published literature, a reasonable conclusion can be made that learning styles do characterize an individual's ability to process information. Even with being held accountable for the standards, "it is possible for [students] to learn in varied, yet appropriate and meaningful ways" (Ferrier, 2007, p. 22). The Learning Preference Checklist (VAK) can be further utilized to incorporate differential learning techniques into classroom instruction and activities. The Kolb Learning Style Inventory (KLSI) can also assist teachers in determining the learning dimension of students and can aid in establishing connections which help link knowledge of the concepts with prior experiences. When used in conjunction with each other, it will be easier to understand how an individual student processes information and will therefore assist in promoting advancement into the critical thinking realm, a region where standards-based questions are concentrated.

Helping students converge and assimilate information forms links of knowledge which can be applicable in novel situations. If applied across interdisciplinary tracts at the high school level, students could benefit in the short term with increased standardized test scores and have increased chances in retaining Georgia's HOPE scholarship at the college level. Individual schools could also benefit directly through the continued renewal of adequate yearly progress, which indirectly has ramifications tied to teacher morale and retention rates.

Recommendations for Action

The level at which teachers differentiate the curriculum in many ways relates to the role of the principal and the administration. The administration's role is of great importance because of the lack of apparent funds to provide for adequate professional development for all teachers. "Teachers tend to imitate the actions, attitudes, and beliefs of those in authority" (Jacobs & Kritsonis, 2006, p. 5). Foremost "strong institutional leadership determines the nature and extent of curriculum integration by teachers" (Jacobs & Kritsonis, 2006, p. 5).

The Role of the Teacher

There is ample evidence to support the fact that real "learning" has to be addressed as it relates to science processing skills and the redelivery of the GPS standards. The LAHS has experienced increases in failure rates of the EOCT biology tests and a minimal decrease in the failure rates of the EOCT physical science tests (see Figures 1, 34) (Governor's Office of Student Achievement, 2007c-d). Teachers must amend their current philosophies and utilize strategies that increase the use of demonstration, questioning, and facilitation skills (Georgia Department of Education, 2007, p. 8) to "guide students as they search for patterns in the information," - the effectiveness of which relies heavily upon the teacher helping students process information (Eggen & Kauchak, 1996).

There are many instructional models that support the redesign of the science curriculum at the LAHS to one that exhibits more of a student-centered focus. These examples include (a) using the best instructional practices exhibited within the local area high school and those within the county level, (b) utilizing *differentiated instruction* (as noted by Tomlinson (2006), Tomlinson & Strickland (2005), and Marzano (2003)),

(c) using *essential questions* to generate further inquiry (Wiggins & McTighe (2005) and Jacobs (1997)), and (d) synthesizing all of this information so that students can gain more out of their experiential learning in chemistry as noted primarily by David Kolb (1984) and other highly noted and respected constructivists.

Differentiated instruction is one of the key philosophies that play a major role in developing classroom environments that attend to learners needs as they are guided through a curricular sequence. This technique enables teachers to be flexible with curricular issues within defined parameters (Tomlinson, 2006). By design it will require teachers to use any paradigm necessary (within reason) so that conceptual knowledge can be developed. Rather than viewing a class as a whole, teachers must view students as a diverse group of individual learners, each having his own perceived learning strengths and weaknesses. Some common instructional methods which may be useful when redesigning a curriculum to fit within the parameters of the GPS frameworks include the following:

1. Identify learners in the classroom (by visual, auditory, and kinesthetic means) so that the delivery of the subject matter content can be delivered in a way that authentically engages a wider variety of students.
2. Use graphic organizers (such as color-coded notes) to help guide learning (see Figures 11-15).
3. Provide materials for further exploration that can answer, "How does this apply/relate to me?" so that the students have a vested interest in the subject matter at hand.

4. Use tiered (or higher order) activities so that students can construct foundations on which they can build conceptual thinking.
5. Use cooperative learning groups to promote discussion and to provide feedback to smaller learner-centered groups.

Essential questions represent a probe into conceptual inquiry which is a key cornerstone to the GPS chemistry curriculum. These questions are used to "frame and guide curricular design" (Jacobs, 1997, p. 27) in such a way that learners explore key concepts. It is through this process that students deepen their understanding (Wiggins & McTighe, 2005).

The Role of the Department

When outside professional development opportunities are unavailable, the science department at the LAHS can self-regulate itself and better facilitate the transition to full GPS operation by establishing horizontal and vertical team meetings. The meetings should be managed in such a manner as to specifically address the gaps experienced from transitioning from an objective-based curriculum to actual (GPS) practice. The horizontal and vertical component allows teachers to communicate issues and curriculum concerns within a subject matter and across the entire discipline of science (within an individual school). Appendix L contains a horizontal team framework designed to cover necessary components for discussion, such as assessment and instruction.

Mentoring all teachers, both experienced and inexperienced, differs from more traditional mentoring programs where, typically, a limited number of new system teachers and their mentors help individuals "understand and negotiate school culture" (Shea &

Greenwood, 2007, p. 31). In many ways this large scale grouping is ineffective because each teacher enters with “differing prior experiences” (Shea & Greenwood, 2007, p. 31). Many science majors are entering the teaching profession today via alternative certification tracts and are adept at functioning within an organizational structure with little training. More attention should be placed on developing a science teachers’ *pedagogical content knowledge*.

Pedagogical content knowledge (PCK), as described by Shea and Greenwood (2007, p. 31), “refers to the knowledge necessary to teach a specific subject and transform student content knowledge into a form accessible to students.” In addition, Rhoton and Bowers (2003) point out that without adequate support in developing this knowledge, many new science teachers will become “too entrenched in routines they learned in college,” which does not represent progression towards standards-based instruction. Developing PCK is comprised of four main components (adapted from Shea & Greenwood, 2007, p. 31):

1. Recognize what distinguishes science from other domains of knowledge.
2. Develop scientific habits of mind.
3. Utilize specific process and manipulative skills used in the discipline.
4. Develop knowledge of how to incorporate analogies, illustrations, examples, and demonstrations into lessons in addition to learning to properly address student preconceptions and misconceptions.

The incorporation of *sustaining conversations* (as discussed by Lambert (2002)) into the horizontal and vertical team meetings is imperative for continued growth. Sustaining conversations are “those that continue… over a period and are essential to sustaining the development of the community" (p. 75). While other mentoring programs end after a period of time - usually at the end of a semester or school year - the development of scientific processing skills cannot end or even become stagnant. While new teachers develop their skills, more experienced teachers, who may have become complacent in their work, may find transitioning to new and perhaps more effective methods of teaching easier. Unless "experiences are created and negotiated together" within a collegial setting which fosters growth, "this development usually does not take place" (Lambert, 2002, p. 80-81). Effective utilization of sustaining conversations could also propagate further discussion of varying classroom instructional methodologies and or research. This provides a forum in which data can be readily disseminated and discussed amongst a group of colleagues teaching the same subject matter.

The Role of the Administration

The role of the administration operating within a local school is probably the most important. The structure in which the administration operates is a product of balancing legislative, regulatory, and policy concerns on one hand with social, community, and interpersonal communication on the other. The necessity of blending formal and informal styles can most assuredly guarantee that some level of dissatisfaction will arise from any decision. Success requires the administration to posses the ability to build a consensus as to the best course of action (Alberta Teachers Association, 2007).

Bureaucratic responsibilities aside, the administration must support all teachers and provide them with what they need (within reason) in order to be successful and progress academically inside and outside the classroom environment. A supporting component to drive this mode of thinking is offered by Abraham Maslow and his *hierarchy of needs*. To establish a path for personal growth, each "lower level must be met before moving to the next higher level" (Huitt, 2004, p.1). For example, student behavioral issues need to be first addressed before planning can commence on increasing the scores on EOCT, GHSGT – SP, and ACT – SRP tests.

Administrators must also be able to successfully translate their vision for achieving goals to their faculty. Jacobs and Kritsonis (2006) point out in their article concerning *Principal's Leadership Behaviors and Skills in Retaining Science Educators* that the main factor that causes science teachers to stay or leave is based upon lack of administrative support and the leadership qualities of the principal (p. 2). If an *effective sustaining* communicative pathway can be established (with emphasis being on both effective and sustaining), teachers will know they are being listened to and supported in their efforts and will have a lesser tendency to migrate to other schools.

Having an effective communicative base will also help to retain highly qualified teachers. If teachers leave due to dissatisfaction, the shortfalls that would result would force school systems to lower standards to fill teacher vacancies (Ingersoll, 2003, p. 1). Data suggests that the way to improve teacher retention is to improve the conditions of the teaching job. One of many such methods is to provide opportunities for professional development (Ingersoll, 2003, p. 10-11). This is an issue especially for new teachers in their first five years (Klentschy & Molina-De La Torre, 2003, p. 67).

Recommendations for Further Research

Based upon the actions, outcomes, and experiences of this research process, it is wholeheartedly believed by this researcher that the intended result of affecting a shift towards the Assimilating domain can be achieved by enacting some small scale changes to the research process. Foremost, initiate the study at the beginning of the school year and or evaluative term so the measurements more accurately reflect the true levels of preexisting knowledge of the concepts. Furthermore, it is recommended that such actions carried out in this process be initiated and carried out via the primary teacher rather than though some second party intermediary (as was the case in this process). This way, one can be more proactive in offering differentiated instructional techniques, rather than reactive. The primary teacher can more readily address problems in situ and more readily create material differentiated (or redirect learning) for each of the learning modalities.

An additional recommendation would be to create and offer shorter concept tests encompassing a single GPS standard which in turn can be utilized as formative assessments rather than offering a broad scale test at the end of a semester in which the primary function is a summative evaluation of learning. This adjustment to the process would be more proactive and would allow a shorter time to react to possible changes which may be needed. Again, this would allow the primary instructor to create material which accentuates learning strengths and builds upon personal experiences.

Another amendment to be considered would be to offer the KLSI on a more frequent basis rather than at the end of the evaluative term. This change would allow the instructor to determine if an individual's approach to problem solving is on the right track. An alternate consideration would be to amend the main constructs of the KLSI itself to focus on an individual's problem solving approach. By using specific Georgia GPS chemistry standards, sentence endings and associated responses could be correlated to each of Kolb's Learning Dimensions. Success could be gauged by monitoring the progression of the results, ideally towards the Assimilating domain.

Implementing the aforementioned recommendations will assist in gaining insight into individual learning styles and how these in turn affect the level of conceptual development in chemistry. Doing so will also make data dissemination more straightforward, thus making it easier to plan and provide multiple levels of differentiated activities to suit the needs and likes of the students within a suitable time frame.

Concluding Statement

The primary objective of this research was to use learning styles to affect a change and shape students' attitudes and orientations towards learning chemistry concepts. Evidentiary findings show that educational experiences are influential when developing a learning style preference, the level of which is established earnestly during one's high school years and further develops as class difficulty increases and there is a greater reliability on applicative processing skills. Furthermore, research shows that people choose individual fields of study which are consistent with their learning styles (Kolb, 1984). The necessary skills to become successful in a field are further honed once students move beyond the foundational aspects. When there is a mismatch between the field's learning norms and an individual's learning style, many times people will either change specialties (or collegiate majors) or leave the field altogether.

Although not conclusive according to the research questions answered in this study, based upon the multitude of research dedicated towards methodologies to improve the student condition, a valid conclusion can be made that learning styles do characterize an individual's ability to process information. Helping students converge and assimilate information forms links of knowledge which can be applicable in novel situations. If applied across interdisciplinary tracts at the high school level, students could benefit in the short term with increased standardized test scores. Long term benefits of using learning styles with the associated use of the KLSI can lead to individuals choosing a career path that matches their ability to process the information, thus promoting the likelihood of success.

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APPENDIX A: PERMISSION TO CONDUCT RESEARCH

Coweta County Schools Research Application, page 3

I understand that no individual participant(s) or school(s) will be identifiable through this research project. I recognize that the research is not complete until a copy of the results is sent to the Director of Testing and Research for the Coweta County School System.

Due to the system's comprehensive academic program, research activities will be conducted during the following months unless special arrangements have been made:

Please attach a copy of all correspondence (cover letter, questionnaires(s), etc. that you intend to send to Coweta County School System staff.

Will students be surveyed as a part of this study? __X YES ___NO

If "YES", please attach a copy of your proposed survey instrument.

I realize that I will be notified in writing concerning the status of this research project within three weeks after the application has been received.

Scott Byrnes ECH **7/20/09**
Signature of Applicant **Date**

Please send this completed application with requested materials to:
Mr. Wayne Outlaw
Assistant Superintendent of Curriculum and Instruction
Coweta County School System
P.O. Box 280
Newnan, Georgia 30264

For System Use Only

Date Application received: 7/27/09

Date Applicant notified: 7/27/09

Approved: ✓ Not Approved:__________

Maria S Carroll
Authorized Signature

7/27/09
Date

APPENDIX B: LOCAL AREA SCHOOL SYSTEM MAP FOR CHEMISTRY

Science Curriculum: General and Advanced Chemistry
Block Schedule

Georgia Performance Standards: Local Area School System Curriculum Map

This document is part of a framework that is designed to support the major concepts addressed in the Chemistry Curriculum of the Georgia Performance Standards through the processes of inquiry. These units are written to be stand alone units that may be taught in any sequence.

1st 4 ½ weeks	2nd 4 ½ weeks	3rd 4 ½ weeks	4th 4 ½ weeks
The Atom	**Patterns and Reactions**	**Relationships**	**Energy and Equilibrium**
Focus: *Introduction to Chemistry* *Analyzing Data* ■ Challenge Problems ■ Dimensional Analysis *Properties of Matter* *Atomic Structure* *Electron Configuration* *The Periodic Table* • Periodicity **General** (►) Use Level 1 and 2 lab exercises when appropriate in all timed block segments. **Advanced** (■) Use Level 3 lab exercises when appropriate in all timed block segments. In addition, include a science fair project and or an element development project. **Both** (•)	***Focus:*** *Bonding* ► VSEPR – Include only 5 shapes (linear, bent, trigonal planar, pyramidal, & tetrahedral) ■ VSEPR - Include hybridization *Reactions* ■ Introduction to net ionic equations *The Mole* *Stoichiometry*	***Focus:*** *States of matter* *Gases* ■ Include Gas Stoichiometry, Dalton's Law, Density, & Graham's Law ► Include gas stoichiometry *Solutions* ■ Include Molality, Freezing point / Boiling Point depression/elevation ► Include Molality	***Focus:*** *Energy* ■ Include Heat of Reaction, Hess' Law, & the Flow of Energy for Phase Change ► Include Heat of Reaction, & the Flow of Energy for Phase Change *Reaction Rates* • Factors effecting reaction rate *Equilibrium* ■ K_{eq} (calculations) ► K_{eq} (concept only) • LeChatelier's Principle *Acids and Bases* ■ % dissociation (calculations) ► % dissociation (concept only) • Arrhenius vs. Bronsted-Lowry, H_3O^+ Concentration and pH, & Acid/Base Neutralization

Each unit integrates laboratory experiences and field work using the process of inquiry. **NOTE:** There are several strategies that are common throughout the units such as the use of a laboratory notebook, written laboratory reports, and common teaching strategies. Keeping in mind that the standards are recursive in nature, it should be noted that many of the standards are revisited in different units throughout the year.	**GPS/End of Course Testing**

APPENDIX C: CHEMISTRY CONCEPTS PRETEST

DO NOT WRITE ON ANY PORTION OF THIS TEST SHEET!

This is a test of your knowledge as it applies to the concepts of chemistry. Use that knowledge to answer all the questions on this examination. Some questions may require the use of the provided *reference sheets.* You are to answer all questions in a manner as directed by your instructor.

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1. An example of a physical property of an element is the element's ability to

   (a) react with an acid
   (b) react with oxygen
   (c) form a compound with chlorine
   (c) form an aqueous solution

2. What is the formula of titanium (II) oxide?

   (a) TiO (c) Ti_2O
   (b) TiO_2 (d) Ti_2O_3

3. Which factors must be equal in a reversible chemical reaction at equilibrium?

   (a) the activation energies of the forward and reverse reactions
   (b) the rates of forward and reverse reactions
   (c) the concentrations of the reactants and the products
   (d) the potential energies of the reactants and the products

4. Which subatomic particles are located in the nucleus of a neon atom?

   (a) electrons and positrons
   (b) electrons and neutrons
   (c) protons and neutrons
   (d) protons and electrons

5. Compared to a phosphorous atom, a P^{3-} ion has

   (a) more electrons and a larger radius
   (b) more electrons and a larger radius
   (c) fewer electrons and a larger radius
   (d) fewer electrons and a smaller radius

6. Which element is malleable and conducts electricity?

   (a) iron (c) sulfur
   (b) iodine (d) phosphorous

7. Which chemical equation is correctly balanced?

   (a) $H_2(g) + O_2(g) \rightarrow H_2O(g)$
   (b) $N_2(g) + H_2(g) \rightarrow NH_3(g)$
   (c) $2NaCl(s) \rightarrow Na(s) + Cl_2(g)$
   (d) $2KCl(s) \rightarrow 2K(s) + Cl_2(g)$

8. Which electron configuration represents the electrons in an atom of chlorine in the excited state?

(a) 2-7-7
(b) 2-7-8
(c) 2-8-7
(d) 2-8-8

9. How do the energy and most probable location of an electron in the third shell of an atom compare to the energy and the most probable location of an electron in the first shell of the same atom?

(a) In the third shell, an electron has more energy and is closer to the nucleus.
(b) In the third shell, an electron has more energy and is farther away from the nucleus.
(c) In the third shell, an electron has less energy and is closer to the nucleus.
(d) In the third shell, an electron has less energy and is farther from the nucleus.

10. Which group on the Periodic Table of the Elements contains the elements that react with oxygen to form compounds with the general formula X_2O?

(a) Group 1
(b) Group 2
(c) Group 14
(d) Group 18

11. Which statement describes what occurs as two atoms of bromine combine to become a molecule of bromine?

(a) Energy is absorbed as a bond is formed.
(b) Energy is absorbed as a bond is broken.
(c) Energy is released as a bond is formed.
(d) Energy is released as a bond is broken.

12. Which isotopic notation identifies a metalloid that is matched with the corresponding number of protons in each of its atoms?

(a) ^{24}Mg and 12 protons
(b) ^{28}Si and 14 protons
(c) ^{75}As and 75 protons
(d) ^{80}Br and 80 protons

13. A bond between a hydrogen atom and a sulfur atom is formed, electrons are

(a) shared to form an ionic bond
(b) shared to form a covalent bond
(c) transferred to form an ionic bond
(d) transferred to form a covalent bond

14. What is the gram formula of $Ca_3(PO_4)_2$?

(a) 248 g/mol
(b) 263 g/mol
(c) 279 g/mol
(d) 310. g/mol

15. Given the balanced equation representing a reaction:

$C_3H_8\,(g) + 5\,O_2(g) \rightarrow 3\,CO_2(g) + 4\,H_2O(g)$

What is the total number of moles of $O_2\,(g)$ required for the complete combustion of 1.5 moles of $C_3H_8\,(g)$?

(a) 0.30 mol (c) 4.5 mol
(b) 1.5 mol (d) 7.5 mol

16. Which two notations represent different isotopes of the same element?

(a) ${}^{6}{}_{4}$Be and ${}^{9}{}_{4}$Be (c) ${}^{14}{}_{7}$N and ${}^{14}{}_{6}$C
(b) ${}^{7}{}_{3}$Li and ${}^{7}{}_{3}$Li (d) ${}^{32}{}_{15}$P and ${}^{32}{}_{16}$S

17. A chemical reaction involving substances X and Y stops when Y is completely used. In this case, Y is the

(a)primary reactant (c)excess reactant
(b)limiting reactant (d)excess product

18. Lithium and potassium have smaller chemical properties because the atoms of both elements have the same

(a) mass number
(b) atomic number
(c) number of electron shells
(d) number of valence electrons

19. Which element is classified as a nonmetal?

(a) Be (c) Si
(b) Al (d) Cl

20. Compared to a proton, an electron has

(a) a greater quantity of charge and the same sign
(b) a greater quantity of charge and the opposite charge
(c) the same quantity of charge and the same sign
(d) the same quantity of charge and the opposite sign

21. Given the balanced equation:

$2\,KClO_3 \rightarrow 2\,KCl + 3\,O_2$

Which type of reaction is represented by this equation?

(a) synthesis (c) single replacement
(b) decomposition(d) double replacement

22. What is the IUPAC name for the compound FeS?

(a) iron (II) sulfate (c) iron (II) sulfide
(b) iron (II) sulfate (d) iron (III) sulfide

23. The molecular formula of glucose is $C_6H_{12}O_6$. What is the empirical formula of glucose?

(a) CHO (c) $C_6H_{12}O_6$
(b) CH_2O (d) $C_{12}H_{24}O_{12}$

24. How do the atomic radius and metallic properties of sodium compare to the atomic radius and metallic properties of phosphorous?

(a) Sodium has a larger atomic radius and is more metallic.
(b) Sodium has a larger atomic radius and is less metallic.
(c) Sodium has a smaller atomic radius and is more metallic.
(d) Sodium has a smaller atomic radius and is less metallic.

25. Which two nuclides are isotopes of the same element?

(a) $^{20}_{11}Na$ and $^{20}_{10}Ne$ (c) $^{39}_{19}K$ and $^{42}_{19}K$
(b) $^{39}_{19}K$ and $^{40}_{20}Ca$ (d) $^{14}_{6}C$ and $^{14}_{7}N$

26. Given the balanced equation representing a reaction:

$$4\ NH_3 + 5\ O_2 \rightarrow 4\ NO + 6\ H_2O$$

What is the *minimum* number of moles of O_2 that are needed to completely react with 16 moles of NH_3?

(a) 16 mol (c) 64 mol
(b) 20. mol (d) 80. mol

27. Which compound contains both ionic and covalent bonds?

(a) ammonia (c) methane
(b) sodium nitrate (d) potassium chloride

28. What is the chemical formula for Iron (II) oxide?

(a) FeO (c) Fe_3O
(b) Fe_2O_3 (d) Fe_3O_2

29. Two different samples decompose when heated. Only one of the samples is soluble in water. Based on this information, these two samples are

(a) both the same element
(b) two different elements
(c) both the same compound
(d) two different compounds

30. Which trends are observed when the elements in Period 3 on the Periodic Table are considered in order of increasing atomic number?

(a) The atomic radius decreases, and the first ionization energy generally increases.
(b) The atomic radius decreases, and the first ionization energy generally decreases.
(c) The atomic radius increases, and the first ionization energy generally increases.
(d) The atomic radius increases, and the first ionization energy generally decrease

APPENDIX D: CHEMISTRY CONCEPTS PRETEST ANSWERS AND STANDARDS COMPARISON

Question #	**New York Regents Test (Month/Year)**	**New York Regents Test Question #**	**Georgia GPS Standard**	**Correct Answer**
1	June 2005	6	SC4b	d
2	June 2005	9	SC1d	a
3	June 2006	21	SC2f	b
4	January 2007	1	SC3a	c
5	January 2007	15	SC4a	a
6	June 2005	7	SC1b	a
7	January 2006	10	SC2a	d
8	January 2006	31	Sc3b	b
9	August 2007	3	SC4a	b
10	August 2007	38	SC1c	a
11	August 2008	12	SC2b	c
12	January 2007	32	SC3c	b
13	June 2008	9	SC3e	b
14	January 2008	34	SC2c	d
15	June 2008	42	SC2d	d
16	January 2008	32	Sc3d	a
17	Self-Produced	N/A	SC2e	b
18	January 2007	11	SC1b	d
19	January 2007	8	SC4b	d
20	June 2005	2	SC3a	d
21	January 2006	37	SC2a	b
22	June 2006	6	SC1c	c
23	June 2005	37	SC2c	b
24	August 2007	34	SC4a	a
25	January 2006	1	SC3c	c
26	January 2007	36	SC2d	b
27	June 2008	37	SC3e	c
28	August 2008	9	SC1d	b
29	August 2005	5	SC4b	d
30	January 2006	7	SC4a	a

APPENDIX E: CHEMISTRY CONCEPTS POSTTEST

DO NOT WRITE ON ANY PORTION OF THIS TEST SHEET!

This is a test of your knowledge as it applies to the concepts of chemistry. Use that knowledge to answer all the questions on this examination. Some questions may require the use of the provided *reference sheets.* You are to answer all questions in a manner as directed by your instructor.

1. Which statement describes a chemical property of oxygen?

   (a) Oxygen has a melting point of 55 K.
   (b) Oxygen can combine with a metal to produce a compound.
   (c) Oxygen gas is slightly soluble in water.
   (d) Oxygen gas can be compressed.

2. Which is the chemical formula for sodium sulfate?

   (a) Na_2SO_3 (c) $NaSO_3$
   (b) Na_2SO_4 (d) $NaSO_4$

3. Which statement must be true about a chemical system at equilibrium?

   (a) The forward and the reverse reactions stop.
   (b) The concentration of reactants and products are equal.
   (c) The rate of the forward reaction is equal to the rate of the reverse reaction.
   (d) The number of moles of reactants is equal to the number of moles of products.

4. An atom is electrically neutral because the

   (a) number of protons equals the number of electrons
   (b) number of protons equals the number of neutrons
   (c) ratio of the number of neutrons to the number of electrons is 1:1
   (d) ratio of the number of neutrons to the number of protons is 2:1

5. What can be concluded if an ion of an element is *smaller* than the atom of the same element?

   (a) The ion is negatively charged because it has fewer electrons than the atom.
   (b) The ion is negatively charged because it has more electrons than the atom.
   (c) The ion is positively charged because it has fewer electrons than the atom.
   (d) The ion is positively charged because it has more electrons than the atom.

6. Which element has both metallic and nonmetallic properties?

   (a) Rb (c) Si
   (b) Rn (d) Sr

7. Which equation shows the conservation of atoms?

(a) $H_2 + O_2 \rightarrow H_2O$
(b) $H_2 + O_2 \rightarrow 2\ H_2O$
(c) $2\ H_2 + O_2 \rightarrow 2\ H_2O$
(d) $2\ H_2 + 2\ O_2 \rightarrow 2\ H_2O$

8. Which two elements have the most similar chemical properties?

(a) Be and Mg
(b) Ca and Br
(c) Cl and Ar
(d) Na and P

9. An ion of which element has a larger radius than an atom of the same element?

(a) aluminum
(b) chlorine
(c) magnesium
(d) sodium

10. Element X reacts with iron to form two different compounds with the formulas FeX and Fe_2X_3. To which group on the Periodic Table does element X belong?

(a) Group 8
(b) Group 2
(c) Group 13
(d) Group 16

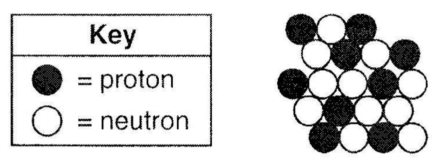
11. Given the balanced equation representing a reaction:

$$Cl_2\,(g) \rightarrow Cl\,(g) + Cl\,(g)$$

What occurs during this change?

(a) Energy is absorbed and a bond is broken
(b) Energy is absorbed and a bond is formed
(c) Energy is released and a bond is broken
(d) Energy is released and a bond is formed

12. The diagram below represents the nucleus of an atom.



What are the atomic number and mass number of this atom?

(a) The atomic number is 9 and the mass number is 19.
(b) The atomic number is 9 and the mass number is 20.
(c) The atomic number is 11 and the mass number is 19.
(d) The atomic number is 11 and the mass number is 20.

13. Which two substances are covalent compounds?

(a) $C_6H_{12}O_6$ (*s*) and KI (*s*)
(b) $C_6H_{12}O_6$ (*s*) and HCl (*g*)
(c) KI (*s*) and NaCl (*s*)
(d) NaCl (*s*) and HCl (*g*)

14. The molar mass of $Ba(OH)_2$ is

(a) 154.3 g (c) 171.3 g
(b) 155.3 g (d) 308.6 g

15. Given the balanced equation representing a reaction:

$2\ H_2 + O_2 \rightarrow 2\ H_2O$

What is the total mass of water formed when 9 grams of hydrogen reacts completely with 64 grams of oxygen?

(a) 18 g (c) 56 g
(b) 36 g (d) 72 g

16. Which isotopic notation represents an atom of carbon-14?

(a) $^{6}_{8}C$ (c) $^{6}_{14}C$
(b) $^{8}_{6}C$ (d) $^{14}_{6}C$

17. The substance not completely used up in a chemical reaction is known as the

(a) limiting reactant (c) excess reactant
(b) limiting product (d) excess product

18. Which statement describes a chemical property of the element magnesium?

(a) Magnesium is malleable.
(b) Magnesium conducts electricity
(c) Magnesium reacts with an acid
(d) Magnesium has a high boiling point

19. Two different samples decompose when heated. Only one of the samples is soluble in water. Based on this information, these two samples are

(a) both the same element
(b) two different elements
(c) both the same compound
(d) two different compounds

20. Which best describes the nucleus of an aluminum atom?

(a) It has a charge of +13 and is surrounded by a total of 10 electrons.
(b) It has a charge of +13 and is surrounded by a total of 13 electrons.
(c) It has a charge of -13 and is surrounded by a total of 10 electrons.
(e) It has a total of -13 and is surrounded by a total of 13 electrons.

21. Given the balanced equation:

$AgNO_3\,(aq) + NaCl\,(aq) \rightarrow$
$NaNO_3\,(aq) + AgCl\,(s)$

This reaction is classified as

(a) synthesis
(b) decomposition
(c) single replacement
(d) double replacement

22. The correct chemical formula for Iron (II) sulfide is

(a) FeS (c) $FeSO_4$
(b) Fe_2S_3 (d) $Fe_2(SO_4)_3$

23. A compound has a molar mass of 90. grams per mole and the empirical formula CH_2O. What is the molecular formula of this compound?

(a) CH_2O (c) $C_3H_6O_2$
(b) $C_2H_4O_2$ (d) $C_4H_8O_4$

24. The data table below shows elements Xx, Yy, and Zz from the same group on the Periodic Table.

Element	Atomic Mass (atomic mass unit)	Atomic Radius (pm)
Xx	69.7	141
Yy	114.8	?
Zz	204.4	171

What is the most likely atomic radius of element Yy.

(a) 103 pm (c) 166 pm
(b) 127 pm (d) 185 pm

25. Which two notations represent atoms that are isotopes of the same element?

(a) $^{121}_{50}Sn$ and $^{119}_{50}Sn$
(b) $^{121}_{50}Sn$ and $^{121}_{50}Sn$
(c) $^{19}_{8}O$ and $^{19}_{9}F$
(d) $^{39}_{17}Cl$ and $^{39}_{19}K$

26. Given the balanced equation:

$$CaCO_3\ (s) + 2\ HCl\ (aq) \rightarrow CaCl_2\ (aq) + H_2O\ (l) + CO_2\ (g)$$

What is the total number of moles of CO_2 formed when 20 moles of HCl is completely consumed?

(a) 5.0 mol (c) 20. mol
(b) 10. mol (d) 40. mol

27. Which formula represents an ionic compound?

(a) H_2 (c) CH_3OH
(b) CH_4 (d) NH_4Cl

28. Which substance has a chemical formula with the same ratio of metal ions to nonmetal ions as in potassium sulfide?

(a) sodium oxide
(b) sodium chloride
(c) magnesium oxide
(d) magnesium chloride

29. Tetrachloromethane, CCl_4, is classified as a

(a) compound because the atoms of the elements are combined in a fixed proportion
(b) compound because the atoms of the elements are combined in a proportion that varies
(c) mixture because the atoms of the elements are combined in a fixed proportion
(d) mixture because the atoms of the elements are combined in a proportion that varies

30. What occurs when an atom loses an electron?

(a) The atom's radius decreases and the atom becomes a negative ion.
(b) The atom's radius decreases and the atom becomes a positive ion.
(c) The atom's radius increases and the atom becomes a negative ion.
(d) The atom's radius increases and the atom becomes a positive ion.

APPENDIX F: CHEMISTRY CONCEPTS POSTTEST ANSWERS AND STANDARDS COMPARISON

Question #	**New York Regents Test (Month/Year)**	**New York Regents Test Question #**	**Georgia GPS Standard**	**Correct Answer**
1	January 2006	5	SC4b	b
2	January 2006	8	SC1d	b
3	June 2005	18	SC2f	c
4	August 2007	2	SC3a	a
5	June 2008	23	SC4a	c
6	August 2007	5	SC1b	c
7	January 2008	9	SC2a	c
8	August 2008	31	Sc3b	b
9	August 2007	14	SC4a	b
10	January 2007	34	SC1c	d
11	August 2007	21	SC2b	a
12	June 2008	33	SC3c	b
13	January 2007	12	SC3e	b
14	January 2007	35	SC2c	c
15	June 2008	36	SC2d	d
16	January 2007	5	Sc3d	d
17	Self-Produced	N/A	SC2e	c
18	August 2007	8	SC1b	c
19	August 2005	6	SC4b	a
20	August 2005	2	SC3a	b
21	August 2005	38	SC2a	d
22	August 2005	9	SC1c	a
23	August 2007	35	SC2c	c
24	June 2005	35	SC4a	c
25	June 2005	3	SC3c	c
26	August 2006	38	SC2d	b
27	August 2007	13	SC3e	d
28	June 2005	36	SC1d	a
29	August 2008	17	SC4b	a
30	August 2005	15	SC4a	b

APPENDIX G: UNIT III (CHEMICAL COMPOSITION) FLEXIBLE SCAFFOLDING WORKSHEET

Unit III: Chemical Composition

I. Essential Questions/Objectives

A. Explain the importance of being able to count by weighing? Use a practical (everyday) and chemistry related example in your response.
B. Explain how atomic mass is determined.
C. What is a mole (mol) and how can it be calculated?
D. What does molar mass represent and how can it be calculated?
E. Explain the process of how one goes about converting amongst moles, mass, and the number of atoms in a sample?
F. How and why are mass percents equivalent to the mass of a substance?
G. How is the mass percent of an element calculated?
H. What are the similarities and differences between empirical and molecular formulas? How can each be calculated?
I. How is the molecular formula in a compound calculated (given its empirical formula and molar mass)?
J. In chemistry was it a hydrate? How can the names of hydrates be determined?

II. **Reading**: Chemistry: Matter and Change → **Chapter #10** (318 - 365)

III. Cooperative Learning Assignments

A. Review

1. Use dimensional analysis to change the given dimension into the second type of dimension (in other words **A → B**). Express all circled final answers in standard scientific notation with the correct number of significant figures.

a.	42 kcal	→	Joules
b.	314.5×10^4 oz.	→	kg
*c.	81 £	→	\$ (32 £ = 46.84 €; \$28 = 23.29 €) *(Express this answer in dollars and cents)
d.	74.6×10^3 inches	→	A.U.
e.	106 km/L	→	mi/gal

2. From the formulas, **write the names** for the following **miscellaneous compounds**:

a. As_8S_4	b. K_3N	c. HCl	d. $Ga_4(Fe(CN)_6)_3$	e. H_2SO_4
f. $NbPO_3$	g. $(NH_4)_2MnO_4$	h. $Fe_5(P_3O_{10})_3$	i. NO_2	j. C_4S_6
k. H_2NH	l. V_3N_5	m. H_2SO_3	n. $BaSeO_4$	o. P_2O_4
p. $H_2B_4O_7$	q. Sn_3As_2	r. H_2O (not water)	s. Tc_4C_3	t. Rb_2O

3. From the names, **write the formulas** for the following **miscellaneous compounds**:

a.	Ammonium zincate	k.	Cobaltous pyrophosphate
b.	Triphosphorous decoxide	l.	Tetraresnic pentiodide
c.	Chromic acid	m.	Aluminum phosphide
d.	Calcium selenide	n.	Vanadium (III) borate
e.	Palladium (IV) oxide	o.	Hydrobromic acid
f.	Hydrophosphoric acid	p.	Heptatellurium nonasulfide
g.	Ferric phosphite	q.	Aresenous acid
h.	Trinitrogen tetrachloride	r.	Aurous phthalate
i.	Phosphoric acid	s.	Boron selenide
j.	Phosphorous hexafluoride	t.	Strontium bromide

B. Name the compounds and count the total number of atoms of each element in the following compounds:

1. $\underline{Al}_2O_3$ 2. $C_6\underline{H}_{12}O_6$ 3. $(\underline{N}H_4)_2SO_4$ 4. $In_4(Fe(\underline{C}N)_6)_3$ 5. $MgS\underline{O_4}$ • $7\ H_2\underline{O}$

C. Determine the molar mass (in g/mol) of each of the compounds in III-B.

D. For each of the underlined elements in Part III-A, determine the percent composition. **Note**: round to 2 decimal points.

*****

Note: Perform the conversions below (**E-H**) via **dimensional analysis**. Be sure to state your **final circled answer in standard scientific notation** with the **correct number of significant figures**.

E. Determine the **mass** (in grams) in each of the following:

1. 8.0 mol of C 2. 12.5 mol of O_2 3. 1.2 mol of NaCl 4. .65 mol of Magnesium hydroxide
5. .23 mol of Sulfuric acid

F. Determine the number of **mol** in each of the following:

1. 281 g of Fe 2. 1.27×10^4 g of Zr 3. 1.90×10^3 g of NH_3
4. 2.11×10^6 g Beryllium borate 5. 4.27×10^4 g Aluminum chromate

G. Determine the number of **atoms** in each of the following:

1. 8.1 mol Au 2. 6.70 mol of Ca_3P_2 3. 372 g K

4. 76.5 x 10^8 g Strontium oxide 5. 18 L Sulfur trioxide

H. Determine the number of **liters** (L) in each of the following:

1. 31.4 g Cl_2 2. 6.8 mol Sb 3. 2.02 x 10^{26} atoms F_2 4. 81 mol Carbon tetrahydride

5. 72.4 x 10^3 g Calcium nitrate

*****

I. Write the empirical formula for each of the following compounds:

1. S_2Cl_2 2. $C_6H_{12}O_6$ 3. C_4H_{10} 4. As_2O_6 5. H_2O_2

J. What is the empirical formula (lowest whole number ratio) of the compounds with the following masses (or mass percentages)? Be sure to show your work via **dimensional analysis**!

1. 75% carbon, 25% hydrogen
2. 52.7% potassium, 47.3% chlorine
3. 32.4 g sodium, 22.5 g sulfur, 45.1 g oxygen
4. 7.99 g carbon, 1.34 g hydrogen, 10.67 g oxygen
5. 2.06%H, 32.69% sulfur, 65.25% oxygen

K. Calculate the molecular formulas based upon the following information:

1. The empirical formula of a compound is NO_2. Its molecular mass is 92 g/mol.
2. The empirical formula of a compound is CH_2. Its molecular mass is 70 g/mol.
3. The empirical formula of a compound is CH_2O. Its molecular mass is 120 g/mol.

L. What are the empirical (A) and molecular (B) formulas of the compounds with the following masses (or mass percentages)? Be sure to show your work via **dimensional analysis**!

4. A compound contains 10.13% carbon and 89.87% chlorine (by mass). Its molecular mass is 237 g/mol.
5. A compound contains 87.5% nitrogen and 12.5% hydrogen (by mass). Its molecular mass is 32 g/mol.
3. A 0.3886 sample of a compound was found to contain mercury and bromine (in that order). 0.1107 g of it was bromine. Its molecular mass was 561 g/mol

APPENDIX H: CHEMISTRY CONCEPTS PEER REVIEWED RESPONSE #1

Byrnes, Scott

From: White, Donald **Sent:** Tue 8/18/2009 3:12 PM
To: Byrnes, Scott
Cc:
Subject: RE: 1st 9 Weeks GPS aligned pre and posttest
Attachments:

I looked at the tests. I like the test questions and the content they cover. My question is what's the point? Are you going to use these tests to measure growth of your students? If so, I think that's valid but you'll need to help them see their growth rather than your students seeing it as another test to pass or fail. About grades, are the kids going to be graded on these tests? If you're using them as "formative assessments" to help you determine your student's progress, you'll need to shorten the time frame of the pre/posttest in order to adjust instruction before moving to another topic. I am actually piloting some formative assessment "probes" at Northgate. They are short quizzes linked to the standards to allow teachers to determine whether the kids understand what's been taught before they move on. They'll be graded via machine to produce data that can be analyzed easily. They can use the data to re-teach or use it longitudinally to adjust instruction for future years. Its just a pilot at this point but you might consider something similar. Also, I like the New York Regents questions but I would focus on the GPS correlation. Referring to NY opens you up to parent and admin complaints about what curriculum you are teaching (New York v. GA). If I were you, I wouldn't even mention NY at all. Those are my professional opinions and I welcome a dialog with you on the subject.

Donald White

Science Content Specialist

Coweta County School System

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http://blogs.cowetaschools.org/curriculum

From: Byrnes, Scott
Sent: Friday, August 14, 2009 7:26 AM
To: White, Donald
Subject: 1st 9 Weeks GPS aligned pre and posttest
Importance: High

Donald,

I would greatly appreciate if you would look over the attached document which contains a GPS aligned pre- and posttest which contains questions from released (public domain) versions of the New York Regents Chemistry Exam. At the end of each test, I have created a table which lists the month, year, and question number of the question which I transferred from the New York Regents Exam. I have also listed the Georgia GPS Standard and the correct answer. I have also created a table which further lists each Georgia Chemistry GPS Standard and the corresponding question contained in the test.

Your comments regarding the representative nature of the tests would be greatly appreciated.

Thank you,

Scott Byrnes – East Coweta High

APPENDIX I: CHEMISTRY CONCEPTS PEER REVIEWED RESPONSE #2

Byrnes, Scott

From: Finger, Kelley **Sent:** Fri 8/28/2009 12:53 PM
To: Byrnes, Scott
Cc:
Subject: RE: 1st 9 Weeks Concepts pre & posttest
Attachments:

Hey Scott – I did have a chance to look it over and I think it looks great. I like the questions from the NY Regents test much better than any other text resource. I definitely like how you aligned the standard with each question. Are you working on a 2nd 9 weeks as well? Good stuff and thanks allowing me the opportunity.

Kelley Finger

Chemistry Department

Newnan High School

-----Original Message-----
From: Byrnes, Scott
Sent: Friday, August 28, 2009 11:11 AM
To: Finger, Kelley
Subject: 1st 9 Weeks Concepts pre & posttest
Importance: High

Kelly,

Have you had the opportunity to review the 1st 9 weeks pre- and posttest that I e-mailed to you? As you can see, these questions are unlike the ones in the Glencoe test bank. I actually selected these questions from released versions of the New York Regents (Chemistry) exams. These questions are much more applicative in nature. My goal is to measure the level of conceptual development attained.

Thank you,

Scott Byrnes – East Coweta High

APPENDIX J: GEORGIA CHEMISTRY PERFORMANCE STANDARDS

Georgia Chemistry Standard	Substandard	Content Descriptor	Reviewed in 1st 9 Weeks
SC1		**Students will analyze the nature of matter and its classifications.**	
	a	Relate the role of nuclear fusion in producing essentially all elements heavier than helium.	**No**
	b	Identify substances based on chemical and physical properties.	Yes
	c	Predict formulas for stable ionic compounds (binary and tertiary) based on balance of charges.	Yes
	d	Use IUPAC nomenclature for both chemical names and formulas: • Ionic compounds (Binary and tertiary) • Covalent compounds (Binary and tertiary) • Acidic compounds (Binary and tertiary)	Yes
SC2		**Students will relate how the Law of Conservation of Matter is used to determine chemical composition in compounds and chemical reactions.**	
	a	Identify and balance the following types of chemical equations: • Synthesis • Decomposition • Single Replacement • Double Replacement • Combustion	Yes
Continued	b	Experimentally determine indicators of a chemical reaction specifically precipitation, gas evolution, water production, and changes to energy to the system.	Yes

	c	Apply concepts of the mole and Avogadro's number to conceptualize and calculate: • Empirical/molecular formulas, • Mass, moles and molecules relationships • Molar volumes of gasses.	Yes
	d	Identify and solve different types of stoichiometry problems, specifically relating mass to moles and mass to mass.	Yes
	e	Demonstrate the conceptual principle of limiting reactants.	Yes
	f	Explain the role of equilibrium in chemical reactions.	Yes
SC3		**Students will use the modern atomic theory to explain the characteristics of atoms.**	
	a	Discriminate between the relative size, charge, and position of protons, neutrons, and electrons in the atom.	Yes
	b	Use the orbital configuration of neutral atoms to explain its effect on the atom's chemical properties.	Yes
	c	Explain the relationship of the proton number to the element's identity.	Yes
	d	Explain the relationship of isotopes to the relative abundance of atoms of a particular element.	Yes
	e	Compare and contrast types of chemical bonds (i.e., ionic, covalent).	Yes
	f	Relate light emission and the movement of electrons to element identification.	**No**
SC4		**Students will use the organization of the Periodic Table to predict properties of elements.**	
Continued	a	Use the Periodic Table to predict periodic trends including atomic radii, ionic radii, ionization energy, and electronegativity of various elements.	Yes

	b	Compare and contrast trends in the chemical and physical properties of elements and their placement on the Periodic Table.	Yes
SC5		**Students will understand that the rate at which a chemical reaction occurs can be affected by changing the concentration, temperature, or pressure and the addition of a catalyst.**	
	a	Demonstrate the effect of changing concentration, temperature, and pressure on chemical reactions.	**No**
	b	Investigate the effects of a catalyst on chemical reactions and apply it to everyday examples.	**No**
	c	Explain the role of activation energy and degree of randomness in chemical reactions.	**No**
SC6		**Students will understand the effects of motion of atoms and molecules in chemical and physical processes.** *Teacher Note: The use of Gas Laws to achieve this standard is permissible, but not mandated.*	
	a	Compare and contrast atomic/molecular motion in solids, liquids, and gases, and plasmas.	**No**
	b	Collect data and calculate the amount of heat given off or taken in by chemical or physical processes.	**No**
Continued	c	Analyzing (both conceptually and quantitatively) flow of energy during change of state (phase).	**No**

SC7		**Students will characterize the properties that describe solutions and the nature of acids and bases.**	
	a	Explain the process of dissolving in terms of solute/solvent interactions: • Observe factors that affect the rate at which a solute dissolves in a specific solvent, • Express concentrations as molarities, • Prepare and properly label solutions of specified molar concentrations, • Relate molality to colligative properties.	**No**
	b	Compare, contrast, and evaluate the nature of acids and bases: • Arrhenius, Bronsted-Lowry Acid/Bases • Strong vs. weak acids/bases in terms of percent dissociation • Hydronium ion concentration • pH • Acid-Base neutralization	**No**

APPENDIX K: CHEMISTRY REFERENCE SHEETS

The Modern Periodic Table of the Elements

Average relative masses are 2001 values, rounded to two decimal places.

All average masses are to be treated as measured quantities, and subject to significant figure rules. Do not round them further when performing calculations.

Key: 80 ← Atomic #; Symbol → Hg; 200.59 ← Avg. Mass; Electronegativity → 1.9

1	2		3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H 1.01 2.1																		2 He 4.00 —
3 Li 6.94 1.0	4 Be 9.01 1.5												5 B 10.81 2.0	6 C 12.01 2.5	7 N 14.01 3.0	8 O 16.00 3.5	9 F 19.00 4.0	10 Ne 20.18 —
11 Na 22.99 0.9	12 Mg 24.31 1.2												13 Al 26.98 1.5	14 Si 28.09 1.8	15 P 30.97 2.1	16 S 32.07 2.5	17 Cl 35.45 3.0	18 Ar 39.95 —
19 K 39.10 0.8	20 Ca 40.08 1.0		21 Sc 44.96 1.3	22 Ti 47.88 1.5	23 V 50.94 1.6	24 Cr 52.00 1.6	25 Mn 54.94 1.5	26 Fe 55.85 1.8	27 Co 58.93 1.8	28 Ni 58.69 1.8	29 Cu 63.55 1.9	30 Zn 65.39 1.6	31 Ga 69.72 1.6	32 Ge 72.61 1.8	33 As 74.92 2.0	34 Se 78.96 2.4	35 Br 79.90 2.8	36 Kr 83.80 3.0
37 Rb 85.47 0.8	38 Sr 87.62 1.0		39 Y 88.91 1.2	40 Zr 91.22 1.4	41 Nb 92.91 1.6	42 Mo 95.94 1.8	43 Tc (98) 1.9	44 Ru 101.07 2.2	45 Rh 102.91 2.2	46 Pd 106.42 2.2	47 Ag 107.87 1.9	48 Cd 112.41 1.7	49 In 114.82 1.7	50 Sn 118.71 1.8	51 Sb 121.76 1.9	52 Te 127.60 2.1	53 I 126.90 2.5	54 Xe 131.29 2.6
55 Cs 132.91 0.7	56 Ba 137.33 0.9	57-70 *	71 Lu 174.97 1.1	72 Hf 178.49 1.3	73 Ta 180.95 1.5	74 W 183.84 1.7	75 Re 186.21 1.9	76 Os 190.23 2.2	77 Ir 192.22 2.2	78 Pt 195.08 2.2	79 Au 196.97 2.4	80 Hg 200.59 1.9	81 Tl 204.38 1.8	82 Pb 207.20 1.8	83 Bi 208.98 1.9	84 Po (209) 2.0	85 At (210) 2.2	86 Rn (222) 2.4
87 Fr (223) 0.7	88 Ra (226) 0.9	89-102 **	103 Lr (262) —	104 Rf (261) —	105 Db (262) —	106 Sg (263) —	107 Bh (262) —	108 Hs (265) —	109 Mt (266) —	110 Uun (271) —	111 Uuu (272) —	112 Uub (277) —	113 Uut (284) —	114 Uuq (289) —	115 Uup (288) —	116 Uuh (291) —		118 Uuo (294) —

*lanthanides	57 La 138.91 1.1	58 Ce 140.12 1.1	59 Pr 140.91 1.1	60 Nd 144.24 1.1	61 Pm (145) 1.1	62 Sm 150.36 1.2	63 Eu 151.97 1.1	64 Gd 157.25 1.2	65 Tb 158.93 1.1	66 Dy 162.50 1.2	67 Ho 164.93 1.2	68 Er 167.26 1.2	69 Tm 168.93 1.3	70 Yb 173.04 1.1
**actinides	89 Ac (227) 1.1	90 Th 232.04 1.3	91 Pa 231.04 1.5	92 U 238.03 1.4	93 Np (237) 1.4	94 Pu (244) 1.3	95 Am (243) 1.3	96 Cm (247) 1.3	97 Bk (247) 1.3	98 Cf (251) 1.3	99 Es (252) 1.3	100 Fm (257) 1.3	101 Md (258) 1.3	102 No (259) 1.3

1-	1 negative
acetate	$C_2H_3O_2$
amide	NH_2
azide	N_3
dihydrogen phosphate	H_2PO_4
hydrazide	N_2H_3
benzoate	$C_7H_5O_2$
bitartrate	$C_4H_5O_6$
bromate	BrO_3
formate	CHO_2
chlorate	ClO_3
chlorite	ClO_2
perchlorate	ClO_4
hypochlorite	ClO
cyanate	OCN
cyanide	CN
hydrogen (bi)carbonate	HCO_3
hydrogen (bi)sulfate	HSO_4
hydrogen (bi)sulfite	HSO_3
hydrogen (bi)sulfide	HS
dihydrogen phosphate	H_2PO_4
hydroxide	OH
iodate	IO_3
maleate	$C_4H_2O_4$
triiodide	I_3
nitrate	NO_3
nitrite	NO_2
permanganate	MnO_4
thiocyanate	SCN
vanadate	VO_3

1+	1 positive
ammonium	NH_4
hydronium	H_3O

2-	2 negative
carbonate	CO_3
chromate	CrO_4
chromite	Cr_2O_4
dichromate	Cr_2O_7
hydrogen phosphate	HPO_4
disulfate	S_2O_7
imide	NH
lactate	$C_2H_5O_3$
manganate	MnO_4
metasilicate	SiO_3
molybdate	MoO_4
oxalate	C_2O_4
peroxide	O_2
peroxydisulfate	S_2O_8
phthalate	$C_8H_4O_4$
sulfate	SO_4
sulfite	SO_3
selenate	SeO_4
salicilate	$C_7H_5O_3$
thiosulfate	S_2O_3
tartrate	$C_4H_4O_6$
tellurate	TeO_4
tetraborate	B_4O_7
tungstate	WO_4
zincate	ZnO_2

3-	3 negative
aluminate	AlO_3
arsenate	AsO_4
arsenite	AsO_3
borate	BO_3
citrate	$C_6H_5O_7$
ferricyanide	$Fe(CN)_6$
phosphate	PO_4
phosphite	PO_3

4-	4 negative
ferrocyanide	$Fe(CN)_6$
pyrophosphate	P_2O_7
orthosilicate	SiO_4

5-	5 negative
tripolyphosphate	P_3O_{10}

6-	6 negative
nesosilicate	SiO_5

Common Equivalents, metric to English, English to metric, English to English

Pressure: 101.325 kPa = 760 torr = 760 mm Hg = 1 atm = 14.7 lb/in^2 (psi)

Mass: 1 gram = 0.035 oz. = 0.0022 lbs   1 lb. = 16 oz. = 0.0005 tons = 0.45 kg   1 metric ton = 1000 kg = 2200 lb

Length: 1 m = 100 cm = 1000 mm = 3.28 ft. = 1 x 10^{10} Å = 1 x 10^6 microns   1 mile = 5,280 ft = 1,760 yd. = 1609 m

1 in. = 2.54 cm   1yd = 3 ft   1 km = 1000 m = 0.622 mile

1 light-year = 6.33 x 10^4 A.U.'s = 9.46 x 10^{12} km   1 parsec = 1.92 x 10^{13} miles = 3.084 x 10^{13} km

Area: 1 ft^2 = 2.3 x 10^{-5} acres = 144 in^2 = 929 cm^2 = 0.093 m^2 = 3.59 x 10^{-8} miles^2 1yd^2 = 9 ft^2

Volume: 1000 mL = 1000 cm^3 = 1000 cc = 1 L   1 gal. = 3.8 L = 4 qt.   1ft^3 = 1728 in^3 1 m^3 = 1000L

Heat (Energy): 1 calorie = 0.004 Btu's = 4.184 Joules   1000 calories = 1 Calorie = 1 kcal = 4,184 Joules = 1 food calorie

Temperature: $T_{celsius} = T_{kelvin} - 273$; $T_{kelvin} = T_{celsius} + 273$ F = 1.8 C + 32   C = 0.556 (F- 32)

Elements with Greek or Latin Names

Na	natrium
K	kalium
Fe	ferrum
Cu	cuprum
Sn	stannum
Sb	stibium
W	wolfram
Ag	argentum
Au	aurum
Pb	plumbum
Hg	hydragyrum

Metric Prefix

1 goes with ↓	= this base unit value
(Y) yotta-	1 x 10^{24}
(Z) zeta-	1 x 10^{21}
(E) exa-	1 x 10^{18}
(P) peta-	1 x 10^{15}
(T) tera-	1 x 10^{12}
(G) giga-	1 x 10^9
(M) mega-	1 x 10^6
(k) kilo-	1 x 10^3
(h) hecto-	1 x 10^2
(da) deca-	1 x 10^1
(d) deci-	1 x 10^{-1}
(c) centi-	1 x 10^{-2}
(m) milli-	1 x 10^{-3}
(μ) micro-	1 x 10^{-6}
(n) nano-	1 x 10^{-9}
(p) pico-	1 x 10^{-12}
(f) femto-	1 x 10^{-15}
(a) atto-	1 x 10^{-18}
(z) zepto-	1 x 10^{-21}
(y) yocto-	1 x 10^{-24}

Tricky Words

Hydrogen =	H^{1+} or H_2
Hydride =	H^{1-}
Hydroxide =	OH^{1-}
Hydrate =	• H_2O
Hydroxyl =	OH

Metallic Valences

*Most common in **bold***

	-ous	-ic
Ag	**1+**	
Cu,	1+	**2+**
Hg_2	**1+**	
Hg		**2+**
Au,	1+	**3+**
Co, Ni, Fe	2+	3+
Pd,	**2+**	4+
Pt	2+	**4+**
Zn, Cd	**2+**	
Sn,	2+	**4+**
Pb	**2+**	4+
Bi	**3+**	5+
As, Sb	**3+**	5+
Lanth'ides	**3+**	4+
Actinides	3+	**4+**

Covalent Prefix		*Organic Prefix*
mono-	1	meth-
di-	2	eth-
tri-	3	prop-
tetra-	4	but-
penta-	5	pent-
hexa-	6	hex-
hepta-	7	hept-
octa-	8	oct-
nona-	9	non-
deca-	10	dec-
	11	undec-
	12	dodec
	13	tridec-
	14	tetradec-
	15	pentadec-
	16	hexadec-
	17	heptadec-
	18	octadec-
	19	nonadec-
	20	eicos-

Helpful Information

$D = m/v$

$\frac{P_1V_1}{T_1}$ $\frac{P_2V_2}{T_2}$

$PV = nRT$

where R is

8.314 L kPa/mol K
or
0.0821 L atm/mol K
or
62.36 L torr/mol K
or
1.206 L psi/mol K

$P_{total} = P_1 + P_2 + P_3 ...$

$Q = S \cdot m \cdot \Delta t$

$pH = -\log [H_3O^+]$

$pH + pOH = 14$

$[H_3O^+] = \text{antilog}(-pH)$

Metallic Activity Series

Cs
Rb
Li
K
Ba
Sr
Ca
Na
Mg
Al
Mn
Zn
Cr
Fe
Cd
Co
Ni
Sn
Pb
H
Cu
Bi
Sb
Hg
Ag
Pt
Au

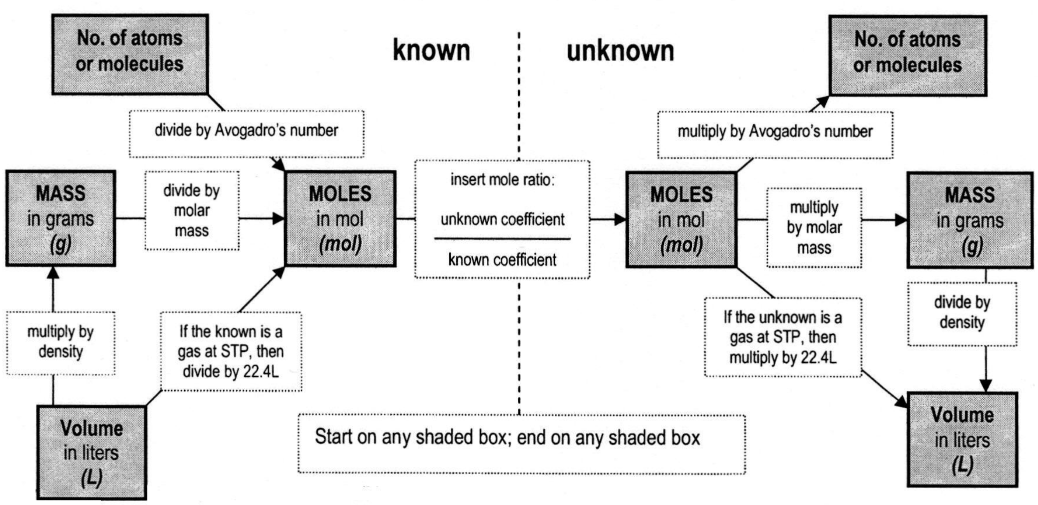
Non-metallic Activity Series

F
Cl
O
N
S
Br
I

Compounds containing these ions are ***soluble*** in water...		...unless they also contain these ions, which makes them ***insoluble***
lithium	Li	
sodium	Na	
potassium	K	
rubidium	Rb	
cesium	Cs	
ammonium	NH_4	
acetate	$C_2H_3O_2$	Fe^{3+} Al^{3+} $Hg_2{}^{2+}$
chlorate	ClO_3	
chloride, bromide, iodide	Cl, Br, I	Ag^+ $Hg_2{}^{2+}$ Pb^{2+}
perchlorate	ClO_4	
nitrate	NO_3	
sulfate	SO_4	Ca^{2+} Ba^{2+} Pb^{2+} Sr^{2+} $Hg_2{}^{2+}$
Compounds containing these ions are *insoluble* in water...		**...unless they also contain these ions, which makes them *soluble***
oxide		
hydroxide		all group 1 metals + Ba^{2+} Sr^{2+} Ca^{2+}
phosphate		all group 1 metals + NH_4
carbonate		all group 1 metals + NH_4
chromate		
sulfite		all group 1 metals + NH_4
sulfide		all group 1 metals + NH_4
silicate		all group 1 metals

Strong Acids	*formula*	Weak Acids	*formula*
chloric	$HClO_3$	acetic	$HC_2H_3O_2$
hydrobromic	HBr	boric	H_3BO_3
hydrochloric	HCl	hydrocyanic	HCN
hydroiodic	HI	hydrofluoric	HF
nitric	HNO_3	hydrosulfuric	H_2S
perchloric	$HClO_4$	hypochlorous	HClO
periodic	HIO_4	nitrous	HNO_2
permanganic	$HMnO_4$	oxalic	$H_2C_2O_4$
sulfuric	H_2SO_4	phosphoric	H_3PO_4
tetrafluoroboric	HBF_4	sulfurous	H_2SO_3

Diatomic: H_2 N_2 O_2 F_2 Cl_2 Br_2 I_2



APPENDIX L: HORIZONTAL TEAM FRAMEWORK SHEET

Horizontal Team Framework Sheet

Department ______________________________ **Subject** ______________________________

Present: ____________________ ____________________ ____________________

____________________ ____________________ ____________________

____________________ ____________________ ____________________

Absent: ____________________ ____________________ ____________________

ASSESSMENT

Data Study

Check any that apply: ___ EOCT ___ GHSGT ___ Teacher Test ___ Benchmark ___ Diagnostic ___ Formative

Standard(s) Addressed: ____

____

Findings: ____

____

____

Ideas for Improvement: ____

____

____

Student Work Study

Check any that apply: ___ Project ___ Class work ___ Test/ Quiz ___ Presentation ___ Lab ___ Performance Task ___ Culminating Assignment ___ Vocabulary Instruction ___ Writing Assignment

Standard(s) Addressed: ____

____

Work Illustrates: ___ Basic Recall of Facts ___ Understanding of GPS ___ Higher Order Thinking

Teacher Commentary: _____ Vague _____ In the Language of the Standards

Discussion Points: (how was topic assigned? what rubric was used? how would the group members assess the work?)

____

____

____

Ideas for Differentiation: ____

____

INSTRUCTION

Shared Assignment

Check any that apply: ___ Project ___ Class work ___ Test/ Quiz ___ Presentation ___ Lab ___ Performance Task ___ Culminating Assignment ___ Vocabulary Instruction ___ Writing Assignment

Standard Addressed: ____

____

How is the assignment presented to the class? ____

What rubric is used? ____

Discussion Points: ____

____

____

Ideas to Differentiate: ____

____

____

Lessons of Success

Standard(s) Addressed: ____

____

Synopsis of Lesson: ____

____

____

Assessment Used: ____

Ideas for Differentiation: ____

____

Instructional Engagement Strategies

___Debate	___Role Playing	___Brainstorming	___Storytelling
___ Think/Pair/Share	___Discussion	___Cooperative Learning	___Jigsaw
___Problem Solving	___Interviewing	___Tutorial Groups	___Centers
___Experiments	___Simulation	___Conferencing	___Technology
___Case Study	___Research	___Other___________________	

Ideas for Implementation ____

____

____

Are we on track with pacing guide? ________ If not, discuss ways to address differences.

Concerns ____

____

____

FOR NEXT TIME

Who will share lesson of success? _______________

Who will bring student work? _______________

What data are we to study? _______________

On which shared assessment will we focus? _______________

Team Leader ______________________ **Meeting Date** ____________

APPENDIX M: KLSI FIGURE PUBLICATION PERMISSION

RE: LSI Figure permission request Monday, March 01, 2010 3:03:13 PM

From: Jessica.Menendez@haygroup.com
To: ssmbyrnes@comcast.net

Hi Scott,

Thank you for your patience while I checked in with the committee regarding your request. It has been approved. You are free to print this figure. Please be sure to mention the LSI tool in your citations.

Thank you.

Regards,

Jessica L. Menendez
Hay Group
116 Huntington Avenue
Boston, MA 02116
(617) 927-5026 (DD)
(617) 927-5008 (F)
www.haygroup.com/leadershipandtalentondemand

From: ssmbyrnes@comcast.net [mailto:ssmbyrnes@comcast.net]
Sent: Thursday, February 25, 2010 7:55 PM
To: Jessica Menendez
Cc: ssmbyrnes@comcast.net; scott.byrnes@cowetaschools.net
Subject: LSI Figure permission request

Jessica.

I have finished my research using , in part, the Kolb Learning Style Inventory. However I wanted to clear up some loose ends before I get final approval on my paper (and I send you my data).

I had also purchased copies of the Kolb Learning Style Inventory (LSI) booklet - Version 3.1. Inside this booklet, is one figure I would like to gain persmision to use. It can be found on page 7. I am attaching a copy of this figure and how I would input it into my paper.

Your response in greatly appreciated,

Scott Byrnes

CURRICULUM VITAE

Scott Byrnes
102 Whisper Creek Drive
Senoia, Georgia 30276
(770) 599-8380
ssmbyrnes@comcast.net

OBJECTIVE To earn my Ed.D. in Teacher Leadership from Walden University.

EDUCATION

Ed.D. Educational Leadership, Walden University, 2010
Thesis Topic: Assimilative Domain Proficiency and Performance in Chemistry Coursework

M.S. Marine Biology, Nova Southeastern University, 1996
Thesis Topic: The Conservation and Management of the Amazon River Dolphin (*Inia geoffrensis*) in South America
Research Experience: 1) The Conservation and Management of the Polar bear (*Ursus maritimus*); 2) The Effects of Lighting Levels on Sea Turtle Hatchling Disorientation Along Broward County, Florida Beaches; 3) The Growth and Development of Freshwater Prawns (*Penaeus sp.)* for Possible Commercial Use.

B.S. Marine Science, Hawaii Loa College, 1992
Research Experience: 1) A Report On Dolphin Behavior, Training, and Husbandry at Kewalo Basin Marine Mammal Laboratory (KBMML); 2) Bathymetry and Sedimentology of the Waters Off Kahaluu Stream Area In Kaneohe Bay, Oahu, Hawaii; 3) Sight is More Significant in the Selection of Food Items than Taste or Smell in Ghost Crabs (*Ocypode sp*.); 4) The Role of Sound Production, Reception, and Analysis in Atlantic Bottlenosed Dolphins (*Tursiops truncatus*).

EXPERIENCE

Educator – 2002-Present
East Coweta High School – Sharpsburg, Georgia 30277
Courses: Advanced Chemistry, Advanced Physics, AP Chemistry, General Chemistry, General Physics, Physical Science, and Science, Technology, & Society

Educator – 2001-2002
Olympia High School – Orlando, Florida 32835
Courses: Advanced Physics, Earth-Space Science, General Physics

Educator – 1998-2001
Forest Park High School – Forest Park, Georgia 30260
Courses: General Biology, General Physical Science

Educator – 1997-1998
Fayette County High School – Fayetteville, Georgia 30214
Courses: Advanced. Biology, Ecology, General Physical Science, Oceanography

Educator – 1994-1996
Cooper City High School – Cooper City, Florida 33328
Courses: Honors Marine Biology, Oceanography

Marine Sea Turtle Specialist – July 1994-October 1994
Florida Department of Natural Resources
Description: Assisted in marine sea turtle extraction, husbandry, release procedures, data acquisition, and reporting.

Educator – June 1994-August 1994
Broward Community College – Fort Lauderdale, Florida 33328
Course: Aquatic Science

Educator – 1993-1994
Marine Science Under Sails (MSUS) - Fort Lauderdale, Florida 33328
Description: Developed and conducted outdoor environmental programs where instruction concentrated on the ecological aspects of coral reefs, wetlands, barrier islands, hardwood hammocks, and mangroves.

Resident Assistant – 1990-1992
Hawaii Loa College – Kaneohe, Hawaii 96744
Description: Supervised dormitory operations and maintained the upkeep and student life activities and general student morale.

Research Assistant – 1990-1991
Kewalo Basin Marine Mammal Laboratory, Honolulu, Hawaii 96801
Description: Conducted behavioral research of marine mammal cognition and maintained the upkeep of the laboratory and four Atlantic Bottlenosed Dolphins (*Tursiops truncatus*).

COMPUTER SKILLS

Proficient in the use of programs (including Microsoft Office, Kaliedagraph, and SPSS) and computer programming languages (Pascal, C+) for Windows and Apple-based computer systems.

SPECIAL ACHIEVEMENT

- Georgia Department of Education (2006)
  - Assisted in the development of exemplar lessons for new Georgia Performance Standards
- Coweta County Leadership Academy (2006)
- Guided a school and county record number of athletes to the Georgia State Swimming Championships (1998).
- Assisted in leading a local water polo squad to a 1st place finish in the Junior National Championships in Fort Lauderdale, Florida (1996).
- Guided the Nova High School (Fort Lauderdale, Florida) Girl's Water Polo team to a 6th place state finish (1996).
- Assisted in leading the Cooper City High School (Fort Lauderdale, Florida) Boy's and Girl's Water Polo teams to a respective 2nd and 6th place state finish (1995).
- Assisted in leading the Pioneer Middle School (Fort Lauderdale, Florida) Boy's and Girl's team to a 1st place regional finish (1995).
- College Scholarship Athlete – Cross Country
  - NAIA District 29 All-Star – 1988, 1990
  - Participated in 30+ road races during this time
    Most Notable: Honolulu Marathon – 1988-1989, 1991
    - Top 10% Overall Finishes: 1988-1989, 1991
    - Top 10% in Age Division: 1988-1989, 1991
- Served in the following organizations while attending college:
  - College Resident and Athletic Assistant
  - Vice-President of College Senior Class
  - College Academic Greek Fraternity
  - College Residence Council