A Study of the Impact of Kinesthetic Learning on Biology Students' Mastery of Protein Structure and Folding Concepts using Legos™

HONORS THESIS

Presented to the Honors Committee of

Texas State University-San Marcos

In Partial Fulfillment of

the Requirements

For Graduation in the University Honors Program

By

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May 2009

A Study of the Impact of Kinesthetic Learning on Biology Students' Mastery of Protein Structure and Folding Concepts using Legos™

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Abstract:

Through a number of personal experiences teaching and tutoring biology courses, as well as having a minor obsession with Legos, I began to ask the question, how can Legos be used in higher education? Current research indicates a shift in student learning styles. Daniel Pink, author of A Whole New Mind, reminds us that “learning isn’t about memorizing isolated facts. It’s about connecting and manipulating them.” Keeping this in mind I developed a pilot study using college level students pursuing degrees in Biology, Chemistry, and Biochemistry. This study compared the use of a didactic lecture and an interactive Lego learning activity to teach a biological concept (protein structure and folding). There were some intriguing and unexpected results. The 11 item pre/post-test of students’ comprehension of the information indicated that students in the Power Point lecture cohort performed higher then the Lego cohort. Interest levels and confidence levels towards the subject taught increased more in the Power Point group than the Lego group. A survey of the students’ learning styles revealed that a majority of the students preferred a multimodal; with a kinesthetic theme reoccurring. The smallest learning style groups were those who solely preferred aural learning or read/write learning. Based on the results and research, creative teaching suggestions were made. Despite the paradoxical results from this small study, additional research must be conducted that measures the long-term retention of the material taught.

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Introduction

This study is designed to assess the impact of kinesthetic learning in college-aged adults on mastery of selected basic biological concepts of protein structure and folding and to identify the implications of these findings on the structure of introductory biology courses at the college level. What is learned through this study combining the disciplines of science and education, may help students experience more academic success in this first course and may provide guidance for the Biology Department at Texas State University – San Marcos in designing potential teaching improvements. This study is designed to answer the research question: Will the students participating in the experimental Lego cohort do either as well or better than the students in the traditional Power Point cohort in terms of their performance on the Biology Department test? The null hypothesis is there will be no significant differences between the performances of both cohorts. A secondary study question is: Will the students in the experimental lecture style cohort who identify themselves as preferring kinesthetic learning consistently perform better on the department test than those who are in the traditional, lecture style? Finally, I may be able to make recommendations to the biology department about ways to integrate similar alternative teaching strategies in future course.

Chapter 1: The Story and the Foundation

When I was four years old, I received a gift that would transform my life forever. It was a gift that not only provided hours of entertainment as a child, but also provided me with a useful resource to develop my educational skills and relieve my stress. My extraordinary gift was a simple Lego™ set. A Lego is a type of building block toy that was developed in Billund, Denmark in the late 1930's by a man named Ole Kirk Christiansen. The present ownership of the Lego Company has stayed within the family with Kjeld Kirk Kristiansen who is one of the grandchildren of Ole Kirk Christiansen (The Lego Group). Since Legos have become a useful tool in my educational experience, I have chosen to study the educational use of Legos in a deeper manner. Before I explain how I will study this, it is important to understand how and why the question was raised, "How can Legos be useful in higher education?"

In my experience, not unlike that of most other students, many classes at the university level consist of sitting in a lecture being barraged with information almost entirely coming from the front of the room. This lack of interaction or application of knowledge in the classroom setting is why many science courses require laboratory experiences. Yet, the labs frequently do not correlate directly with the lecture. According to research conducted, there is about a 35% drop/failure/withdrawal rate for students in introductory science courses (Dharmasiri and Aspbury, personal communication). To address this academic concern, Texas State established a service on campus called the Student Learning Assistance Center (SLAC).The student tutors, called Supplemental Instructors (SI's), are always finding new and successful ways to help students understand the concepts presented in lecture.

The Vision Statement of SLAC is "to instill confidence in Texas State students and assist them in becoming independent learners who rely on their strengths and abilities." (http://www.txstate.edu/slac/). Looking at the statistics released by SLAC regarding its success over the past three years, there have been some interesting outcomes. The average number of students who attend and participate in the tutoring sessions in the program has steadily increased from 7,892 (Fall 2006) to 10,260 (Fall 2008). Focusing on the Fall 2008 semester, one may see that 20% of participants were seeking help in the sciences, and 37% of these participants were freshmen students (http://www.txstate.edu/slac/about/all-statistics.html). This is important to recognize because it supports the notion that there are significant numbers of freshmen students seeking help in the sciences at Texas State.

In my experience as a frequent visitor to the SLAC lab, I have learned that SLAC provides students with an opportunity to teach themselves and their peers primarily; a tutor is available to assist. As one keeps in mind the number of students seeking assistance in the sciences, SLAC has indicated that the fall 2008 students who participated in this style of peer-taught learning had an average GPA that was .32 higher than non-participating students (http://www.txstate.edu/slac/). The Biology Department does not participate in the SLAC program, but has its own version of SI's. My experience as a Biology Department Supplemental Instructor (SI) made me curious to explore alternative teaching techniques I realized that after being tutored, tutoring others and observing the effects of creative, alternative teaching techniques, I found that students were more successful when a variety of perspectives and strategies for learning were available to them. This observation sparked my interest in asking the research questions on which I am basing this study.

Chapter 2: Learning with Style

In order to know if Legos ™ are useful tools in the task of teaching students in higher education, an understanding of different learning styles and various brain functions is helpful. There is an extensive body of research, as well as empirical evidence, that confirm the notion that each individual learns differently (Feldor, 1993; Bransford, 1999; Pink, 2006). That is, individuals take in and process information from their environment in ways that are particular to them. Common classifications of learning styles include: visual (spatial), aural (auditory-musical), verbal (linguistic), physical (kinesthetic), and logical (mathematical). Each of these learning styles is characterized by how the individual not only prefers to learn, but also describes how they best retain and process information. Recognizing these differences in learning has led to a body of knowledge in the field of education that has revolutionized teaching practice in the last 30 years. (http://www.lsda.org.uk/files/PDF/1543.pdf).

A visual learner, for example, prefers to use pictures or images and spatial relationships, an auditory learner prefers using sound and/or music to learn. A verbal learner prefers words, both in speech and writing to take in information. Mathematical/logical learners prefer using reasoning, systems, and logic to learn. Physical or kinesthetic learners absorb and process information best when using their body, hands and sense of touch.

The science of neurology confirms that different parts of the brain are responsible for these different functions. The field of neurology and now the capacity for brain imaging helps us to understand the role of different areas of the brain for various sensory functions related to learning. Auditory functions are managed by the temporal lobes with the right temporal lobe important for music. Verbal functions are managed by the temporal lobes and the frontal lobes, especially two areas in the left hemisphere known as the Broca's and Wernicke's areas (Paulesu, Vallar, Berlingeri, Signorini, Vitali, Burani, Perani, Fazio, 2009). Visual sense is processed through the occipital lobes in the rear of the brain. The parietal lobes, in coordination with occipital lobes, manage spatial orientation. Physical movement is managed much of the time by the cerebellum and the area at the back of the frontal lobe known as the motor cortex (Brain Injury Resource Center, 1998).

It is no surprise then, that variations in the structure and function of individuals' brains indicate that each person is "hard wired" slightly differently for learning. Moreover, these individual variances are evidenced in the ability of individuals to display talent and/or develop skills in music, mathematics, writing or athletics. Dr. Antonio Damasio states in his book, Looking for Spinoza, that "one of the key purposes of our educational development is to interpose a nonautomatic evaluative step between causative objects and emotional responses." (Damasio 54). What he is indicating is that our educational system is designed to teach us how to think more independently from our emotions. He proposes that our ability to recall information is strongly connected to our emotions and personal experiences. There is considerable research in the field of education, including adult education, about variations in learning styles and how teaching techniques and strategies can be modified to accommodate these variations. However, in the field of higher education, there is little research done on studying the importance of integrating the information that students receive in class, with more hands on (kinesthetic) techniques.

College students are in transition between learning in an education system designed for children and a system designed for adult learning. In elementary and high school, teachers may have used a variety of teaching techniques to address various learning styles. However, in higher education, as young adults, students are typically expected to learn through a primarily linguistic-focused teaching style, such as lecture. As there is evidence that student success and retention in college is highly correlated with academic success early in their college years it is helpful to explore ways that a university system and in particular, introductory level courses can contribute to student self-efficacy and expectations for success, which are predictors of college science performance (Singh 14).

Richard Feldor, a science educator at the University of North Carolina who has authored 17 articles pertaining to student learning styles in science education, conducted an interesting analysis which exposed the issue of the shortage of scientists in my generation. Looking at many science courses, Feldor and other researchers recognized that there are two types of students; those who go on to earn science degrees and "those who have the initial intention and the ability to do so but instead switch to nonscientific fields." While exploring the cause of this more, these researchers observed some interesting issues. They found that professors teach in the methods that suit their own learning style, which is not necessarily best for the students they are teaching. Feldor continues by saying:

> *"…the teaching style in most lecture courses tilts heavily toward the small percentage of college students who are at once intuitive, verbal, deductive, reflective and sequential. This imbalance puts a sizeable fraction of the student population at a disadvantage. Laboratory courses, being inherently sensory, visual, and active, could in principle compensate for a portion of the imbalance; however, most labs involve primarily mechanical exercises that illustrate only a minor subset of the concepts presented in lecture and seldom provide significant insights or skill development. Sensing, visual, inductive, active, and global learners thus rarely get their educational needs met in science courses."(Feldor, 1993).*

With their intellectual needs not met, this large fraction of students will lose interest in the material being taught. Eventually, this passive attitude will turn into a total disinterest in the subject, causing an increase in the second type of student mentioned earlier.

This is a serious retention issue that must be addressed in many universities on a national scale and at Texas State. Thus, it makes sense for both students and course instructors to recognize various learning styles and look for ways to adapt the intake of information in ways that help ensure mastery of the content. An educational researcher, John Bransford, states that "[teachers] must not only know their own way around a discipline, but must know the conceptual barriers likely to hinder others." (Bransford, 144). This includes things like the student reading information aloud if he/she is an auditory learner or for a kinesthetic learner, physically manipulating concepts on index cards in a particular order. To improve academic performance, it may be beneficial for the individual college-age learners to *1)* recognize their own learning style and understand that they likely have a mix of learning styles; *2)* be able to create or request teaching/learning strategies that build on various learning preferences or strengthens the student's ability to learn in other ways where possible. To help improve student performance, it may be helpful for university departments to consider how to integrate kinesthetic and other techniques improve the quality of student learning and result in improved retention of concepts and overall academic.

What is learned through this study in the Biology program may help place the department in a position to better meet the needs of students in the program. The Common Experience theme at the University for the 2009-2010 Academic Year is called "A Whole Mind", named after the book called A Whole New Mind by Daniel Pink. The author calls on us to address the way we teach and learn to reflect changes in the world of life-after-college that will require this generation to move into more conceptual and "right brained" thinking compared to more "left-brained" careers (e.g. accounting, engineering, etc.) that have marked recent decades. Pink's arguments are logical and very compelling. He reminds us that "learning isn't about memorizing isolated facts. It's about connecting and manipulating them." (Pink 193).

This is all crucial in this global economic situation. In fact, according to The Cambridge Handbook of The Learning Sciences, one finds that the since the world economy is changing, the future leaders of this world must learn to change as well. That is why countries all over the world are updating their education systems to allow "students to think flexibly, creatively, and collaboratively." (Cambridge University Press 567). Pink is clearly not the only one to recognize that something must be done. After reading this book I was inspired to articulate my curiosity into a simple question, how can playing be incorporated into higher education?

Chapter 3: The Hard Part

Throughout all of my readings and casual discussions with various students and professors, I have found that this topic is of the utmost importance. Specifically recalling how Legos™ have helped me, I decided to perform a unique study using Legos™ with college students. Since there is nearly no research done on using Legos™ to specifically enhance college students' mastery of a subject in biology, my proposed project ultimately sought to help college students in an introductory biology course at Texas State University. Regardless of self identified learning style preference, I wanted to see how use of manipulating Legos™ could help them master basic biology concepts of protein structure and folding. Students were assigned to the Lego and Power Point cohorts and compared on the learning outcomes of these concepts based on whether they received usual instruction (i.e. didactic lecture) or usual instruction plus kinesthetic-based instruction using Lego-brand™ building block kits designed to teach these concepts.

3.1: Visit to MIT/Obtaining Legos

When I originally explored the possibility of using Legos™ to teach, the biological concepts that I hoped to explore was photosynthesis and cellular respiration. On the Lego

Education website, I found a set that was designed to teach this concept. Due to the relatively simplistic nature of the set, I contacted the Lego Education branch and they directed me to contact the set's designer/author, Dr. Kathy Vandiver from the Massachusetts Institute of Technology. She agreed to assist me in re-designing the set and the lesson plan. Over winter break, I went up to the MIT campus and met with Dr. Vandiver. During the visit she asked me what I thought about the Lego amino acid set that she designed to teach students about protein folding and structure. In that moment, I knew that this was the biological concept I was meant to teach. Currently there are only 10 of these amino acid Lego™ sets; Dr. Vandiver had two and the MIT museum had eight. After my visit, it was agreed that I would use all 10 of these sets in my study.

3.2: Grant process

Originally, I applied for the honors grant for the purchase and shipment of the Lego™ sets that I was going use in my study. As I explained earlier, the Legos™ were loaned to me for the mere cost of shipping and handling, but this was after the awarding of the grant. The changes were addressed to the grant proposal and approved. Grant funds were used to cover this cost, the cost of photocopying lesson materials and surveys, the cost of pizza, and the $5 incentive paid to each student participant. However, in spite of the provided incentives student participation was limited and not all of the money was used. Please refer to Appendix Table 4 for allocation of grant money.

While the grant application was being processed, I applied for an exemption from the Institutional Review Board (IRB). Considering my experiment involved students, I needed the approval of the board to continue my study. Fortunately, my exemption request was approved because all students were invited to participate in the study on a volunteer basis and agreed to participate by signing in at the session and receiving payment.

3.3: Recruiting/Timing of study (before lecture in class)

As I returned from MIT, I contacted the professors teaching the freshman biology class to determine when they planned on lecturing about protein structures and functions. It was important that these students were not exposed to this concept in class yet so that I may obtain accurate results. Unfortunately, they were lecturing merely 2.5 weeks after my return! Over the course of two weeks, I managed to complete a number of tasks that were needed to prepare to launch the study. The first task was to recruit students to participate in my study. I made an agreement with the professors to provide students with extra credit if they participated. After a few days of recruiting, I had over 100 students sign up to participate! The students who signed-up for a specific trial were not aware if they were in the Power Point cohort or Lego cohort.

3.4: The Lesson Structure and Development

The second task was to develop and perfect the experimental design. The lesson plan for each trial was meticulously scheduled to assure the most consistent experimental controls. From testing times to lighting in the room, all details needed to be the same in each lesson; except the use of Legos™ or Power Points. There were four trials conducted. Two trials were using a traditional didactic power point presentation, and two trials were using the 10

Lego™ sets provided by MIT. I reserved a classroom in the Supple Science Building that could fit about 38 students.

Along with reserving the room, I needed to develop the pre and post tests. These tests allow me to see the progress of students before and after the lesson. The tests asked questions about the principles of protein structure and folding and evaluated student interest levels as well as their confidence levels. The pre-test had an attached survey called the Visual Aural Read/write Kinesthetic (VARK) Questionnaire. This questionnaire was designed by Neil Fleming as a way for organizations to evaluate the preferred learning styles of their members. The VARK survey was only used in the pretest. The post-test consists of the same questions as the pre-test, only without the VARK survey. The survey was used with permission of Dr, Fleming.

On the day of the first two trials, there were a few tasks to complete. First, I needed to open the room and cover the windows so that curious students would have no idea which study they were a part of; the Power Point cohort or the Lego cohort. I also ordered pizza and made photocopies of the tests. When the trials began, students entered the room and were asked to sit in order of arrival at desks labeled #1- #22. The start time began in a punctual manner. I spent one minute to introduce myself, explain what I was doing, what the rules of the study were (i.e. no cell phones, no leaving, etc.). One rule that I enforced was no note-taking. By allowing students to take notes, I would be introducing another learning style; writing. After the introduction, I provided students with 15 minutes to take the pre-test.

After the pre-test was collected, I began the Lego™ lesson. Due to the limited number of Lego™ sets, I was forced to have two students working per set. After the pre-test, they moved their desks into pairs so that they may each have opportunity to ‘play’ and learn with the Legos™. In the power point lesson, the students sat in their seats as they listened to me. In both types of lessons, students were allowed to ask questions. I set aside 40 minutes to cover the lesson in each trial. Once the lesson was over, the post-test was distributed and students were given 10 minutes to complete the exam. When they were done, they signed out, received their five dollars, and left with smiles on their faces! The trials were completed within an hour. Inventory was taken of every amino acid within every Lego™ set before and after each lesson in which they were used.

3.5: The Content

The content of both lesson styles contained the same main goals and common principles of protein structure and folding. The first principle was to provide a general overview of the various types of common amino acids; hydrophobic, hydrophilic, acidic, and basic. The second principle was protein folding and structure. It was important for students to have a thorough understanding of the chemical structures that comprise amino acids. Therefore the lesson also included a review of the primary, secondary, tertiary, and quaternary structures into which these amino acids folded. Finally, I reviewed how structure leads to function. I briefly covered how these specific sequential structures affected the ability of a cell to survive using the example of sickle cell anemia.

Each question, or item of the pre-/post-test covered a different principle or concept presented in the lesson. Item number one tested for an understanding that there are 20-22 common amino acids found in nature. This was covered in the Lego™ lesson as students took inventory of twenty types of amino acid Legos™. The Power Point lesson presented this concept in the form of a table. Test item number two tested for the concept that when reading an amino acid sequence, one reads from the carbon-terminus to the nitrogen-terminus. This was covered in the Lego™ lesson as students needed to rotate the Lego™ amino acid in order to connect and fold the sequences properly. In the Power Point lesson, this principle was presented as an image of an amino acid sequence with labels. Item number three tested for an understanding of hydrophilicity. The Lego™ lesson had students build a specific amino acid sequence and fold the object until the hydrophilic amino acids were facing an outward position, and hydrophobic were facing an inward position. The Power Point lesson used written text and showed a picture of a folded sequence with labels of the hydrophilic and hydrophobic regions.

The fourth item tested for an understanding of the structure to function relationship and the impact of mutations. The Lego™ lesson did not formally teach this. The Power Point covered this by showing an example of how the amino acid sequence of a normal red blood cell mutated into sickle cell anemia. The fifth test item quizzed students about the different types of amino acids. The Lego™ lesson taught this through the types of storage compartments the Lego™ kits had for each amino acid. Students discovered this when they took inventory of the Lego™. The Power Point lesson presented this concept in table form.

Test item number six tested for a structural concept affiliated with glycine's lack of an R-group. The Lego™ lesson expressed this by not giving the glycine amino acid a building brick on the side where all the other amino acid Legos had bricks representing R-groups. The Power Point expressed this by showing the Lewis structure of the amino acid compared to other amino acids. Item number seven tested for the main principle of modern biochemical genetics; DNA is transcribed into RNA and then translated into proteins. The

Lego™ lesson did not teach this concept directly. The Power Point lesson displayed "DNA→RNA→protein", which was expressed in the same manner as the post-test.

Test item number eight tested for an understanding of structure stability through various bonds between amino acids. The Lego™ lesson expressed this as students assembled the amino acids and when they formed a secondary structure. The Power Point lesson displayed an image of two bonding amino acids and labeled the areas of interest. Test item number nine tested another structural concept pertaining to cysteine's unique ability to form disulfide bonds. The Lego™ lesson taught this as students connected two cysteines with a little blue hose that could only fit and attach to the knob extending out from that specific amino acid. The Power Point lesson taught this by displaying an image of a disulfide bridge. The last two test items asked for students to grade their levels of interest and confidence towards the material taught on a scale of 1-10 (10 = the most confident).

Chapter 4: So What Happened? (Results)

Due to financial limitations, I could only afford to pay 88 students to participate in the study for $5 each. Fifty-three students attended and participated in the study, about half of the number of students who signed up initially. Twenty-four students participated in the Power Point lecture and twenty-nine in the Lego™ lecture.

4.1: Pre-test vs. post-test results

When comparing the two Lego™ lectures, there appeared to be various strong points and weak points. Regarding the quiz questions, there was an overall positive increase in knowledge of the content taught. This study also observed interest and confidence levels with participants. Initially, the average pre-test scores between both lessons were relatively even with 43% as the average for the Lego™ lesson and 42% as the average for the Power Point lesson. In the post-test scores one may see that the Power Point lesson appeared to perform better with 81% than the Lego lesson which had a 59% average score. Table 1 and Figure 1 below express these results.

Table 1. *Average test scores for pre-test and post-test between lesson types.*

	Pre-test	Post-test
Lego Lesson	43%	59%
Power Point	42%	81%

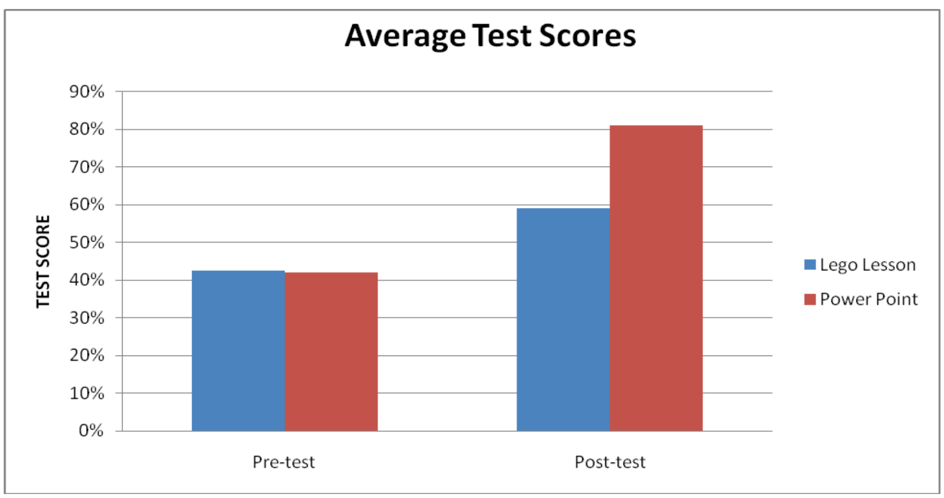

Figure 1. *Average test scores for pre-test and post-test between lesson types.*

In order to understand these results further, a breakdown of scores for student performance on each test item was completed. Student improvement was quantified as a percent change between pretest and posttest. For each question, I looked at the number of students in the trial who changed their answers from incorrect at pre-test to correct answers at post-test for that item. The scores are presented as a percent of trial participants with correct changes. All the results from the students were then averaged together to represent the entire experimental cohort's performance. The average percent of change per question within the Power Point and Lego™ trials was calculated and compared by compiling the percent of change for each type of lesson. Finally, the results for the correct change of each question under varying lesson types were recorded and graphed as seen below in Table 2 and Figure 2.

Key finding: In the Lego™ cohort at post-test, there was a 9% average increase in the overall level of interest in the material and about a 93% average increase in students' confidence about the material compared to the pre-test. Refer to Table 2 and Figure 2 for more detailed results.

Table 2. *This table provides a comparison of the percent change for each test item between the two Lego™ lectures*

% Change by Item between Pre- & Post-tests for Lego Lessons												
	Test Item										Observed Change b/w Pre- & Post-test scores	
	#1	**#2**	**#3**	**#4**	**#5**	**#6**	**#7**	**#8**	**#9**		**Interest**	**Confidence**
Trial #1 (Lego)	43%	200%	33%	0%	117%	-60%	-50%	0%	83%		9%	67%
Trial #4 (Lego)	100%	300%	8%	57%	200%	100%	550%	100%	-75%		9%	119%
Avg. % Change	**72%**	**250%**	**21%**	**29%**	**159%**	**20%**	**250%**	**50%**	**4%**		**9%**	**93%**

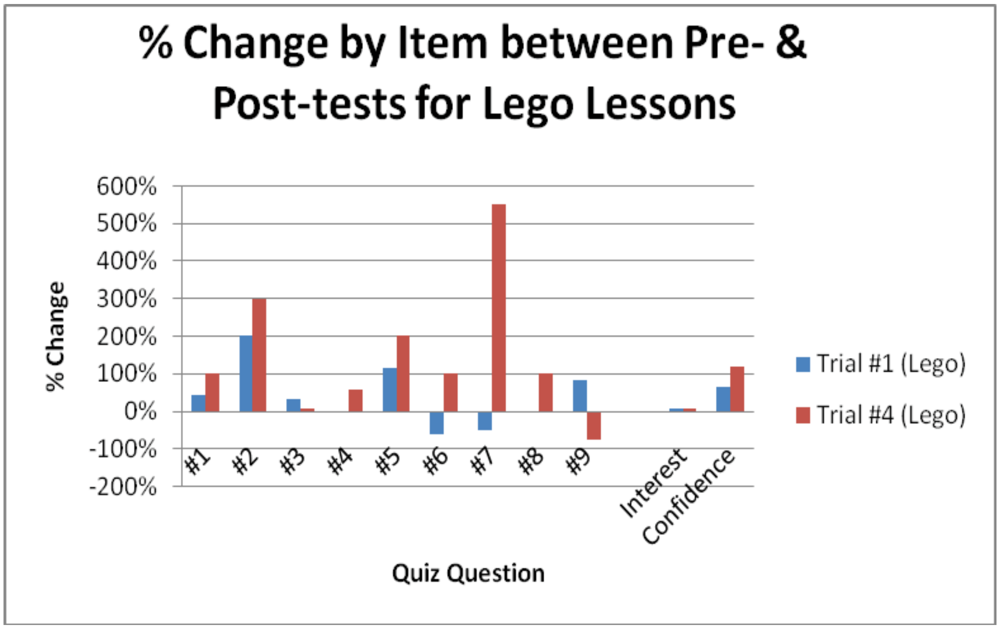

Figure 1. *This chart expresses the percent change in student answers for each test item for both Lego™ lectures, as well as the percent change of interest and confidence levels towards the material taught.*

When reviewing the results of the two Power Point lectures, there appeared to be a very strong and consistent change in the number of questions students answered correctly after the lesson was completed. There was an extremely large increase in the knowledge of the material taught. Also, there was an average increase of about 34% in student interest and a 285% increase in student confidence towards the material presented. Refer to Table 3 and Figure 3 for more details on the results of the Power Point lectures.

***Table 3**. This table provides a comparison of the percent change in student answers between pre- and post-test for the two power point lectures. (Traditional Power Point Method)*

% Change by Item between Pre- & Post-tests for Power Point Lessons												
	Test Item										Observed Change b/w Pre- & Post-test scores	
	#1	#2	#3	#4	#5	#6	#7	#8	#9		Interest	Confidence
Trial #2 (PPT.)	167%	700%	11%	25%	700%	500%	67%	80%	600%		46%	379%
Trial #3 (PPT.)	86%	700%	0%	75%	100%	-40%	86%	50%	225%		21%	191%
Avg. % Change	127%	700%	6%	50%	400%	230%	77%	65%	413%		34%	285%

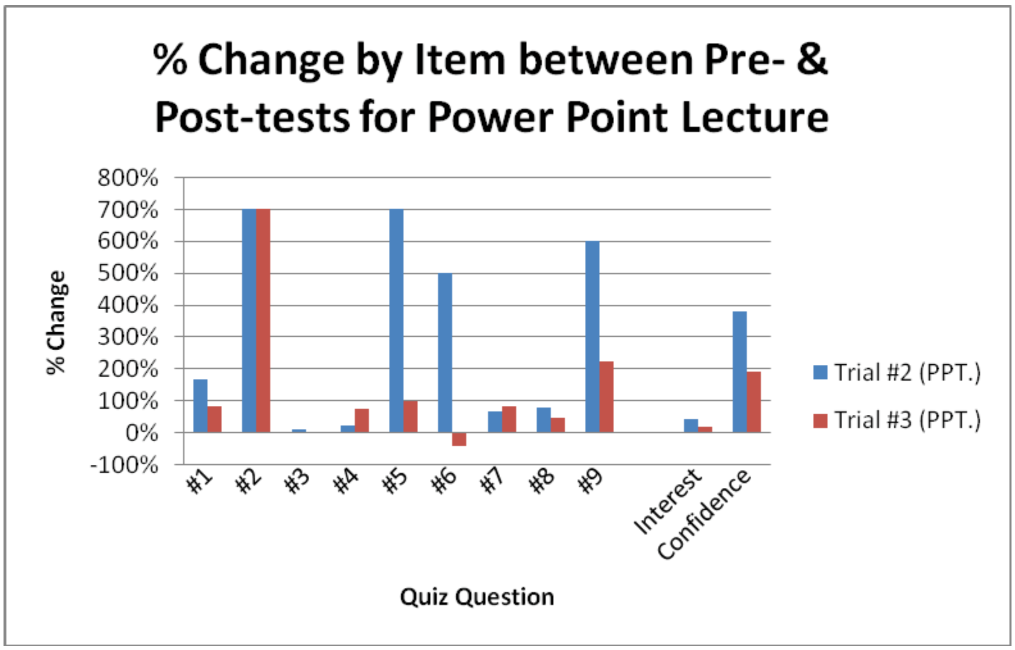

***Figure 3.** This chart expresses the change of student answers on the quiz, as well as the percent change of interest and confidence levels towards the material taught during the Power Point lectures.*

When comparing the differences in the overall success of student participants, the results were interesting. It was determined that the Power Point lecture style was more successful in presenting the lesson goals to the biology students than the Lego™ lecture style. For a majority of the questions on the educational content, the Power Point lecture showed a greater percent change in the number of questions students answered correctly. There was also a 25% difference in the interest levels with the Power Point showing the greater increase. Comparing the confidence levels, there was a 192% difference with the Power Point showing the greater increase. Refer to Table 4 and Figure 4 for a clearer portrayal of the differences of the percent change between the Lego™ and Power Point lectures.

***Table 4**. This table provides a comparison of the percent change between both the Lego and Power Point lectures.*

% Change by Item between Pre- & Post-tests for Both Lectures												
	Test Item										Observed Change b/w Pre- & Post-test scores	
	#1	#2	#3	#4	#5	#6	#7	#8	#9		Interest	Confidence
Lego Lesson	72%	250%	21%	29%	159%	20%	250%	50%	4%		9%	93%
PPT Lesson	127%	700%	6%	50%	400%	230%	77%	65%	413%		34%	285%

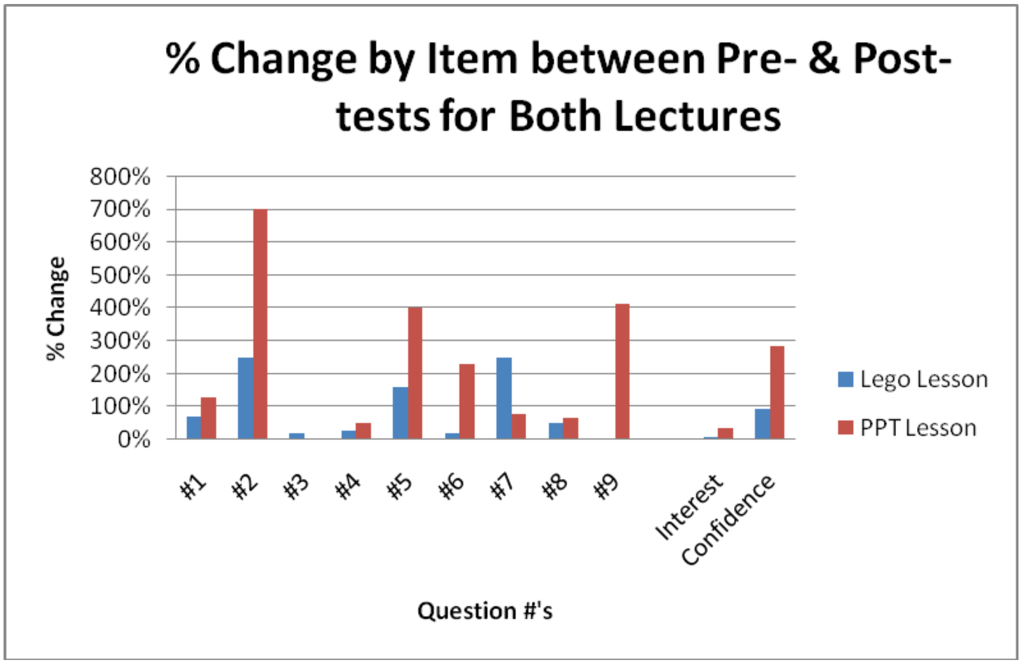

***Figure 4.** This chart compares the change of student answers on the quiz, as well as the percent change of interest and confidence levels towards the material taught between the Lego and Power Point lectures.*

4.2: VARK results

Using the VARK questionnaire, I was able to analyze and compare the various learning styles of the students pursuing degrees in Biology (24 students), Biochemistry (4 students), Chemistry (3 students), and other unrecorded degrees (22 students). Figure 5 shows the distribution of learning preferences amongst the sampled cohort. A majority expressed a preference for multi-modal learning with 68%, 21% preferred only kinesthetic, 5% preferred only visual, 4% only reading/writing, and 2% preferred aural. Multi-modal learners are those who prefer more than one learning style. Since this investigation is examining kinesthetic learning, this preference's prevalence was compared to the rest of the learning styles found within the sample, including the multi-modal students. The most common preference 'theme' was kinesthetic with 63%. This may be observed in Figure 6.

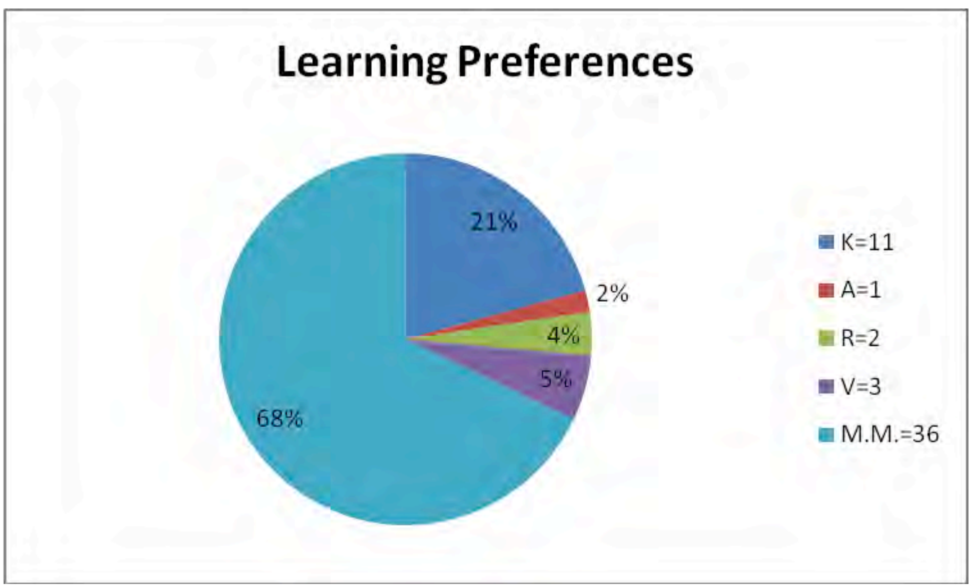

Figure 5. *This chart displays the learning preferences found among the sampled students.*

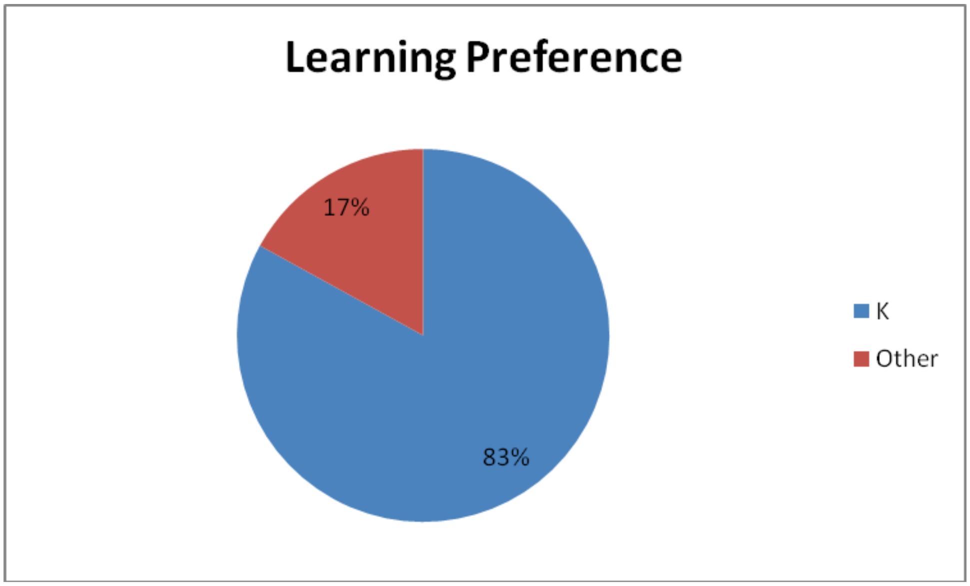

Figure 6. *This chart displays the prevalence of a kinesthetic learning preference within the sample.*

Figure 7 shows the relationship of the varying majors that students have and the learning styles calculated by the VARK analysis program for each individual student. It appears that the strongest learning preference theme among Biology majors in this study was a kinesthetic style. The same was true for Biochemistry majors although the numbers are too small to be statistically significant. As for Chemistry majors in this study, it was observed that visual and reading/writing are most preferred. The fourth subgroup of majors is a random mix of majors categorized as ‘Other’ on the pre-test. A majority of these students have some preference to a kinesthetic learning style.

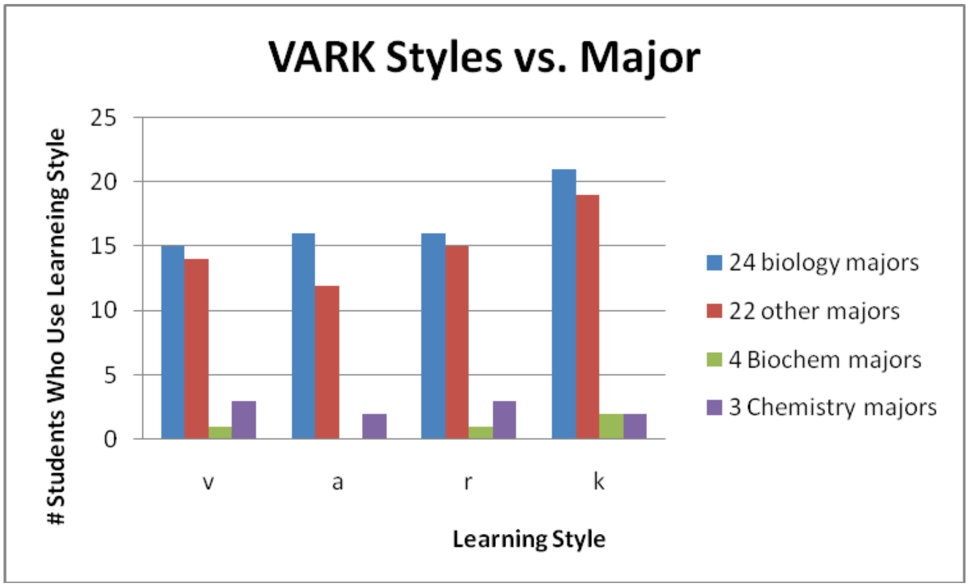

Figure 7. *This chart expresses the relationship between students' learning style preferences and their majors.*

4.3 Statistical Analysis

Tables 5 and 6, present a t-test statistical evaluation of the presence of a significant difference between the pre-test and post-tests between each lesson type. When the P-value is less than 0.05, there is a significant difference present. The P-value for the Lego™ lesson was 4.82E-05 and the P-value for the Power Point lesson was 1.1E-09. There was a greater significant difference through the Power Point lesson than the Lego™ lesson.

Table 5. *This table provides a statisical evaluation of the Lego lessons and indicates a significant difference between the pre and post-tests.*

LEGO

t-Test: Paired Two Sample for Means

	Variable 1	*Variable 2*
Mean	0.43295	0.586207
Variance	0.02235	0.023718
Observations	29	29

Pearson Correlation	0.283954
Hypothesized Mean Difference	0
Df	28
t Stat	-4.54369
P(T<=t) one-tail	4.82E-05
t Critical one-tail	1.701131
P(T<=t) two-tail	9.65E-05
t Critical two-tail	2.048407

Table 6. *This table provides a statisical evaluation of the Power Point lessons and indicates a significant difference between the pre and post-tests.*

Power Point

t-Test: Paired Two Sample for Means

	Variable 1	*Variable 2*
Mean	0.425926	0.810185
Variance	0.038289	0.017691
Observations	24	24
Pearson Correlation	0.312796	
Hypothesized Mean Difference	0	
Df	23	
t Stat	-9.44806	
P(T<=t) one-tail	1.1E-09	
t Critical one-tail	1.713872	
P(T<=t) two-tail	2.21E-09	
t Critical two-tail	2.068658	

Chapter 5: What Does All This Mean? (Discussion)

5.1: Observations during study

Throughout the process of developing and conducting the study I wrote down various observations about how students conducted themselves. There were a few interesting observations to address. The first significant observation was seen during my recruiting process. When I invited the class to participate in this paid study ($5 each), about 10-20 students raised their hands in interest. Seeing that I was struggling for participants, the professor mentioned that there would be 5 extra credit points and the majority of the class raised their hands. What I concluded from this observation was that, to these students, a few points that will hardly affect their grade are more valuable than money!

Another interesting observation was the reaction students had when they found out which teaching style was presented to them. Since they did not know which style they had as they entered into the classroom, their reactions were fresh. Students who had the Power Point lecture immediately slouched in their chairs and almost all of them folded their arms to brace for a boring presentation. The students in the Lego™ lecture actually perked upright in their seats and became fidgety. It was almost as if they suddenly time-traveled beck to a time where learning was fun, new and exciting. When I mentioned that there would be two students per set, the students began to move their desks together and created little stations without any instruction from me. The classroom soon looked like a mature version of a kindergarten class! There was a real energy that began to fill the room. Unfortunately, the Power Point lesson had a sense of boredom and exhaustion.

5.2: Implications of pre/post test results

The pre/post test results were quite unexpected. My original hypothesis was that the students who participated in the Lego™ study would perform superior to those in the Power Point study; the results showed otherwise. The Power Point presentation was more effective in this investigation. Although my hypothesis was not supported, the theory behind it is not completely ruled out. There were a number of factors that may have caused a significant impact on the results of student participation. The first major factor was the items tested in the pre/post-tests. Test items 4, 7, and 9 (relationship of structure to function; transcription of DNA/RNA into proteins; formation of disulfide bonds) did not directly address the concepts students were learning through interaction with the Lego™ sets. Item number nine had the potential to teach this but there were an insufficient number of the plastic hoses needed for all the students.

Test items #3 and #7 were the only two items where the Lego™ lesson performed better than the Power Point lesson. As a way of understanding these results, one may look at educational researcher Benjamin S. Bloom's taxonomical evaluation of educational objections. The levels range between one and six (Bloom, table 9-1). The lowest level (1) refers to one's ability to memorize information, and the highest level (6) refers to one's ability to evaluate, judge and critique information. Scores nearest to level six support Daniel Pink's statement that "learning isn't about memorizing isolated facts [but rather] it's about connecting and manipulating them" (Pink 193). Test item #3 tested for an understanding of hydrophilicity and the Lego™ lesson had students rearrange and fold the Legos™ to express this principle. This form of problem solving is a Level 3 on Bloom's evaluation which indicates one's ability to apply knowledge to solve problems and find solutions. The Power Point approach displayed an image of a hydrophobic/hydrophilic structure and listed their definitions underneath the image. This would be considered a Level 1 on Bloom's evaluation; simple memorization of information. Question #3 applied a higher level of knowledge manipulation in the Lego™ lesson than the Power Point lesson, therefore these results are logical.

Test item #7, asking about the genetic principles of transcription and translation, displayed some unique results. This question would remain on Level 1 since a fact was simply presented and no manipulation of knowledge was needed. Since the only involvement students in the Lego™ cohort had with this principle was holding the final product, proteins, it is not clear how they performed better on this item than the Power Point students.

The next major factor affecting these results may be seen in the amount of time spent on each lecture. In order to maintain a controlled environment, I needed to match the timing of each lecture as closely as possible. The Power Point presentation was easily completed quite thoroughly within 20-25 minutes. On the other hand, the Lego™ lecture was very rushed and completed in 30-35 minutes. Since there was so little time to spend on each concept with the Legos, students were unable to "play". As soon as they completed the structure of one protein they needed to disassemble it and build a new one, thus not allowing them to discover and explore the structures enough. I realized that the Power Point presentation allows professors to give a lot more information in a shorter period of time and is a very useful tool. The Lego™ lecture would work ideally in a lab setting with more time, space, and resources. Felder and fellow science educator R. C. Wilson (Wilson, 1983), presented evidence that an active classroom that allows for discussion and problem-solving will most likely produce students who can recall the information presented on a long-term scale.

The next factor involved was my personality. When I presented the Lego™ lecture, it was easy for me to be excited and interested. Unfortunately that excitement dwindled as I began to be rushed for time. My anxiety may have been sensed by the students, thus making them a little more stressed as well. In the Power Point presentation, students came into the room disappointed and not as excited when they learned that they were not in the Lego™ trial. This is when I made a few jokes and used comical analogies throughout the lecture. Eventually the students that were slouching at the beginning of the lesson were sitting upright and maintaining eye contact by the end of the presentation. This made me also realize how much the attitude of the presenter affects the interest level of students as well as, more importantly, the level of confidence they have on the material taught.

One more factor may have been the timing and format of the post-test. In the Power Point lesson, a majority of the concepts were presented at Bloom's Level 1 manipulation of information. Therefore, the results may be expected to be higher if a test of knowledge was given immediately after it was presented. In the Lego™ lesson, knowing the information enough to test on it successfully immediately afterward was proven difficult. This is because the information was not prepared in a format for memorization, but rather manipulation. The multiple choice format and the Bloom's level of a majority of the questions on the pre/post-tests appealed to students receiving information on a level of memorization (i.e. through a power point). A more accurate observation of this study would be seen if students were tested after a longer period of time elapsed between the lesson and test. Also, a change may have been seen if the testing format were not multiple choice. Each of these factors, as well as the presence of a few tardy students, the absence of many, and a few missing Lego™ pieces, significantly affected the outcome of this study.

The paired T-test used to evaluate the data showed that both lesson styles displayed a significant difference between the pre-test and post-test. This means that both lesson styles were effective. Comparing the two styles against each other, one may see that the Power Point displayed an even greater difference in results than the Lego™ lesson.

5.3: Implications of VARK Results

The other aspect of the study included observation of the current learning styles of students in the Biology 1430 course. The VARK analysis showed that the most common learning style incorporated the combination of visual, aural, read/writing, and kinesthetic. The second most common preferred learning style was by students who solely preferred a strongly kinesthetic style. The least common learning styles were by students who solely preferred aural or only read/writing. In my experience, and according to Felder, most biology courses in higher education are designed to appeal to these least common styles; this is unfortunate. According to these results, the multi-modal and the kinesthetic learning styles are the most common and preferred forms of learning among the students participating in a biology course for science degrees at Texas State. What these results show is that professors must develop alternative ways to appeal to the varying learning needs of the students in addition to the didactic power point presentations.

5.4: Teaching Ideas

After brainstorming with students in varying degree fields and professors who are known for teaching in alternative ways, I have a few suggestions and ideas to address some of the needs that emerged through my study. One possibility may be to vary delivery of content across class periods, avoiding use of Power Point presentation for every session. Instead, have students work in twos and threes on certain topics and have them teach their peers in a way that does not incorporate a Power Point presentation. This idea alone will provide many new and creative techniques for professors to adopt that students may find successful for them.

Another suggestion, made by Wilson in his article, "Improving Faculty Teaching: Effective Use of Student Evaluations and Consultants", may be for professors to “provide opportunities for reflection, such as giving students time in class to write brief summaries and formulate written questions about the material just covered.” This will allow students a moment to ‘digest’ their lesson before they run to their next class. Science educators, Avi Hofstein and Vincent Lunetta, collaborators from Weizmann Institute of Science and Penn State University wrote an article evaluating science labs in education in the 21st Century. This article supports Wilson’s idea of allowing students time to reflect and ‘digest’ their information.

Another suggestion may be for professors to try having students set aside a piece of paper at the beginning of lecture. Toward the end of the lecture, students will fill in the paper with an image that they thought of during the lecture (pertaining to the lesson in some way). Along this idea, it is possible to have students take notes through drawing pictures. There is a unique notebook, called Interactive Notebook that is designed for the specific purpose of allowing students the opportunity to write down notes in an organized way and then compliment their own notes with images they drew (Chesbro, 2006). I know this idea works because I designed my own form of this notebook which I found to be successful during my art history and world history courses. Drawing allows students to compact a lot of information into a simple image. After all, a picture is worth a thousand words!

5.5: How would I do things differently next time?

Unfortunately, there were some limitations to my protocol. As a result there are a number of things I would do differently if the opportunity to conduct this experiment arose again.

1) The sample size is largely a sample of convenience and participants are volunteers. These are important factors because this limits the ability to generalize the findings to any other course, subject matter or students. It would work best if there were a more concrete commitment by student participants and a larger variety of students.

2) I also would like to have had more Legos™ for the students to use. Having students share sets worked, but not everyone got the full experience due to the limitations of having to share Legos™ and space.

3) I would not pay the students, because their response towards extra credit was more significant than their response to money.

4) During the Power Point presentation, I would cut back on my charisma, or I would maintain the charisma during the Legos™ lecture. Another idea would be to have someone else present the information who does not have a bias towards Legos™, because this could have potentially had a significant effect on the results.

5) I would allow students in the Lego™ lecture more time to discover and explore with the Lego™ sets.

6) I would have liked to have more students participate in the study to provide a more respectable sample size.

7) These results may be more interesting and accurate if compared to other basic biology courses that are not directed towards science degrees. As addressed by Felder earlier, many students are opposed to or unsuccessful in science courses, not necessarily because of an inability to learn the information, but rather because the material is not being taught to them in a way that appeals to their learning style. By exploring this route, I hope to see how students' interest levels may change and possibly rekindle a desire to pursue a scientific career. I also hypothesize that a majority of the students interested in science, but are in alternative career paths, are kinesthetic learners who were discouraged by the 'boring' nature of trying to pursue a scientific degree.

8) I also would have like to design the pre/post-tests in a different way. I would like to address all of the Bloom's levels of educational objectives in the tests. To accurately test these I would design the tests in a manner that was not completely in a multiple choice format.

9) Finally, I would have liked to provide a follow-up test a month after the lesson, to see how well students remembered the material. When Felder described the difference between students who are sensors (those who like facts and observation) and intuitors (those who like concepts and interpretations), he stated that there were a number of studies comparing professor-centered classes with student-centered classes. It was found that lectures were "more effective when students were tested on short-term recall of facts". Yet, "active classroom environments were superior when the criteria involved

comprehension, long-term recall, general problem-solving ability, scientific attitude, and subsequent interest in the subject."

5.6: <u>A Quick Response to This Observation</u>

This observation exposes the unfortunate obsession over grades that professors, employers and parents have instilled in students. The current system of 'making the grade' is slowly killing students' desire and understanding of what it means to learn. As mentioned earlier by Dr. Antonio Damasio, "one of the key purposes of our educational development is to interpose a nonautomatic evaluative step between causative objects and emotional responses." We may do this by utilizing knowledge that we have gained to evaluate and devise an optimal response to any stimulus. If we are not retaining knowledge in a long-term manner, then the quality of our responses to various situations may not be optimal for our individual or communal survival. It is imperative that this issue is address nationally, but executed on a local level.

A common concern of professors, which was also an observation within my study, is that there is too much information to present in such a limited amount of time. In my experiences traveling around the world (i.e. Brazil, New Zealand, Australia) I have found that, the United States of America seems to be one of the few countries to have students go through high school and then get an undergraduate degree before they get advanced degrees necessary for their desired profession. Most countries with large universities have students go straight into the schools of their desired professions and do not repeat the information presented in high school as seen in much of the undergraduate degrees. Even though other countries like New Zealand do not repeat, it does not necessarily mean it is better. Repetition is healthy, but over repetition may be perceived as unnecessary. The first two and a half years of my undergraduate education essentially repeated the majority of my high school courses. It was not until the end of my time here at Texas State that I feel like I am learning new information pertaining to my future career path. I would suggest the government re-evaluate the need for such over repetition in the first two years of one's undergraduate experience. As seen abroad, those first two (or three) years are modified and the last year or two are added on to the graduate curriculum.

5.7: Overall thoughts about success of study/hypothesis (What I Learned)

Despite the minor errors and unexpected factors involved in the study, as well as the rejection of my hypothesis, I felt that this study was an overall success. Even though my predictions were contradictory to the results, I did manage to learn a few things about teaching styles. The first was that Power Point presentations are one of the best ways to present many ideas in a in a thorough way over a short period of time. The second was that most students are in desperate need of alternative teaching methods to satisfy their diverse learning styles. The third is that students in this study found the incentive for grade points more important than a cash incentive. It may be possible that $5 was not enough, but unless this study is conducted again or if another study is conducted exploring this topic then we may never know the true answer to that. The fourth is that lessons taught using Legos™ may best belong in a lab setting with more space and time. Finally, I found that Legos™ bring out the kid in almost everyone who interacts with them. This is crucial for the maintenance and rejuvenation of one's imagination and creativity. I feel my study will be one of the first of many, due to the changing times. Yet, though the economy and political situations are shifting, one thing has remained unchanged for 70 years, Legos™ and imagination!

A Special Thanks to:

Dr. Sandra West for being my advisor and mentor throughout this entire process. You have helped me out significantly and I am very grateful.

Dr. Kathy Vandiver, from MIT, for trusting me with the Legos™ you designed and the opportunity to conduct this pilot study.

Dr. Sunethra Dharmasiri and **Dr. Susan Michelle Green** for volunteering your time, power points, extra credit points, and for providing me with students for this study.

Professor Diann McCabe for motivating me to get this idea off the ground and moving.

Dr. Heather Galloway for editing and reviewing my paper, as well as being a fellow Lego™ enthusiast.

Mrs. Andrea Ferreira for being my mother and helping me out in more ways than I can count!

Professor Diane Silva-Pimentel for being my high school biology professor who gave me a ‘C’ yet sparked my interest in biology and never gave up on me!

Thank you all very much for the help, support, and interest in the success of this study!

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Appendix

Grant Dispersal:

Table 4 provides the dispersion of money provided by the grant received from the University Honors Program at Texas State University.

Table 4. Total Expenditures for Lego study using $500 grant.

ITEM	Expense
Pizza Costs	**$75.30**
Lego Shipping Costs	**$86.07**
Misc. Supplies	**$14.61**
Student payment ($5 ea.)	**$265**
Total Expense	**$440.98**
Surplus	**($59.02)**

IRB E-mail Confirmation:

Exemption Request EXP2008U9892 - Approval
ospirb@txstate.edu [ospirb@txstate.edu]

Sent: Thursday, November 20, 2008 1:11 PM
To: Ferreira, Matthew T

DO NOT REPLY TO THIS MESSAGE. This email message is generated by the IRB online application program.

Based on the information in IRB Exemption Request EXP2008U9892 which you submitted on 11/18/08 10:55:14, your project is exempt from full or expedited review by the Texas State Institutional Review Board.

If you have questions, please submit an IRB Inquiry form:

http://www.txstate.edu/research/irb/irb_inquiry.html

Institutional Review Board
Office of Research Compliance
Texas State University-San Marcos
(ph) 512/245-2314 / (fax) 512/245-3847 / ospirb@txstate.edu

JCK 489
601 University Drive, San Marcos, TX 78666

Pre/Post Test For Lego Study:

1. The amount of common amino acids found in nature is:

A. 10-12
B. 34-38
C. 20-22
D. 50-55
E. 70-80

2. When reading a sequence of amino acids the N-terminus is on the ____ and the C-terminus is on the _____.

A. Top, Bottom
B. Bottom, Top
C. Left, Right
D. Right, Left

3. Compounds that are attracted to water are called:

A. Hydrophobic
B. Prohydric
C. Hydrophilic
D. Hydrophate
E. Antihydric

4. If a mutation occurs in the ________ structural level of a protein, then the function of the protein will most likely be affected.

A. Primary
B. Secondary
C. Tertiary
D. Quaternary
E. None of the above

5. Which of the following is not a category of amino acid types?

A. Polar
B. Prohydric
C. Hydrophobic
D. Weak Acidic
E. Weak Base

6. Which amino acid does not have an R-group?

A. Lysine
B. Glycine
C. Alanine
D. Glutamine
E. Cysteine

7. The "central dogma" of modern biochemical genetics, pertaining to the flow of inherited information, states that information moves as diagramed here:

A. Protein→RNA→DNA.
B. DNA→RNA→protein.
C. DNA→protein→RNA.
D. RNA→DNA→protein.
E. RNA→protein→DNA

8. What type of bond connects amino acids?

A. Peptide
B. Glycosidic
C. Van der Waals
D. Polar

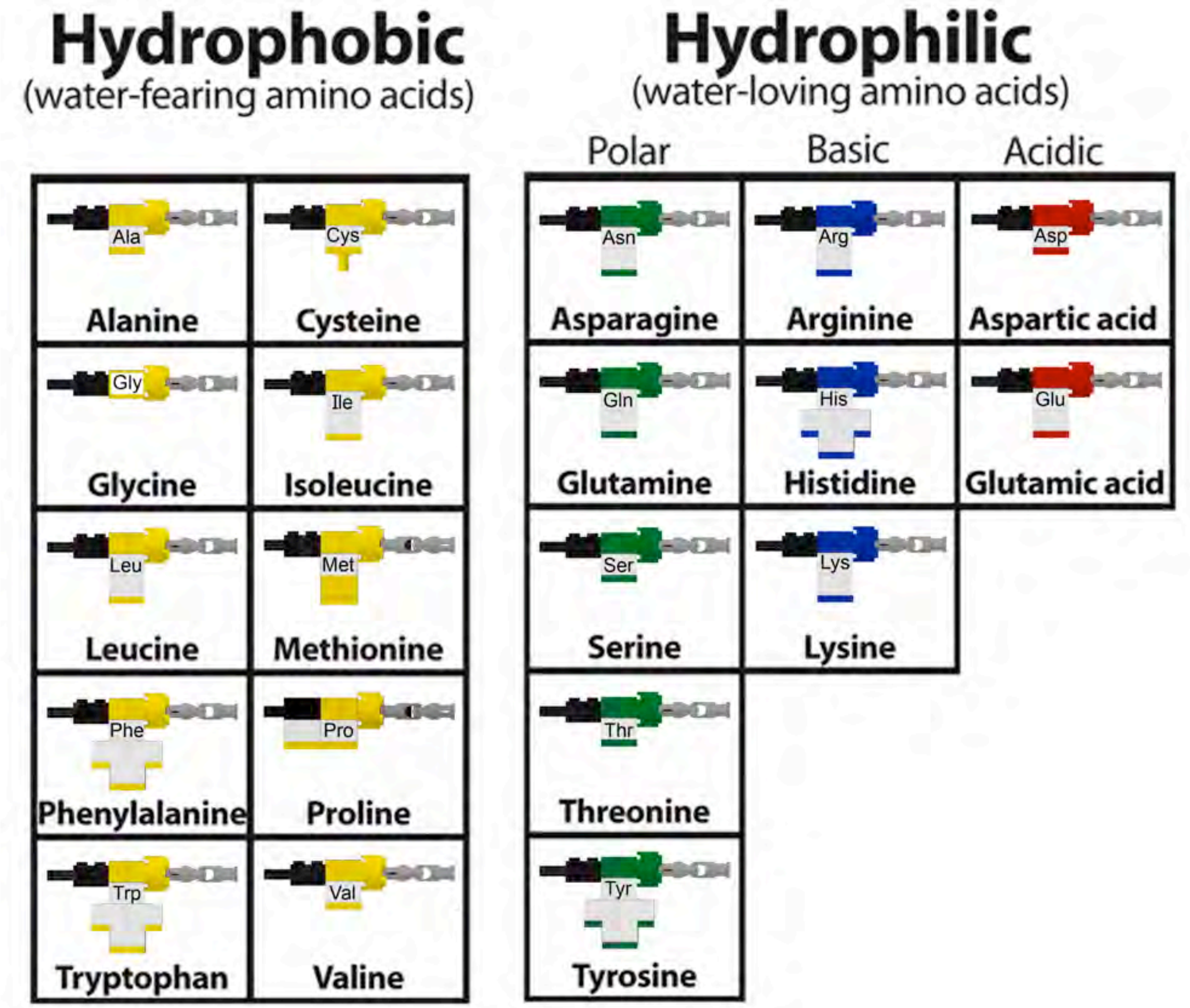
What is your level of interest in protein structure and folding? (1= not interested at all, 10= very interested)

____

How confident do you feel about your score on this quiz? (1=not confident at all, 10= Very confident).

____

Legos Used:


Hydrophobic
(water-fearing amino acids)
Hydrophilic
(water-loving amino acids)
Polar
Basic
Acidic
Ala
Alanine
Cys
Cysteine
Gly
Glycine
Ile
Isoleucine
Leu
Leucine
Met
Methionine
Phe
Phenylalanine
Pro
Proline
Trp
Tryptophan
Val
Valine
Asn
Asparagine
Arg
Arginine
Asp
Aspartic acid
Gln
Glutamine
His
Histidine
Glu
Glutamic acid
Ser
Serine
Lys
Lysine
Thr
Threonine
Tyr
Tyrosine