The Use of Modeling Clay in High School Biology Vocabulary Acquisition

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ABSTRACT

The purpose of this study was to determine the effectiveness of vocabulary acquisition in high school biology using modeling clay. A mixed methods explanatory sequential design was used with modeling clay in contrast to sentence writing. The 96 student participants, comprising five classrooms, were all from Georgia public high schools in the southwest region of the state. The schools, from lower socio-economic status, were all Title I schools.

The treatment activity consisted of students creating depictions of the definitions of words in physical forms with modeling clay. The control group wrote sentences demonstrating an understanding of the word. The posttest was administered after the twenty cell unit words and twenty genetics unit words were completed by all students. The retention test was completed the week following the posttest. Likert-style student surveys were completed at the same time as the retention test. The teacher interviews were conducted after each unit, guided by ten questions related to classroom layout, planning lessons, management of students during the study, and opinions and impressions regarding the use of clay in pedagogy.

The use of clay as a kinesthetic tool was determined to be effective, and in some cases better, than traditional methods of vocabulary acquisition. The use of clay allowed students to approximate experiences with microscopic entities in alignment with multisensory practices like kinesthetic intelligence and DCT theories. Per the quantitative data from participating teachers and assessment results, males performed better with the use of clay. The study also validated the findings of Marzano (2010) who stated that vocabulary should be addressed as a separate subject. This study serves to validate other studies regarding the use of kinesthetic or tactile approaches to learning education and is a springboard to future studies employing unconventional learning methods.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

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DEDICATION

This dissertation is dedicated to my father, Dr. Robert J. Bailey. As a medical doctor for over forty years, an ordained minister, and a Navy captain, he has tacitly set goals for me his entire life. He has been my hero. I have always been so proud of his accomplishments. Even though we discussed my dissertation many times, my only wish is that he could have been here for the completion.

Although my father passed while I was working on my dissertation, he was with me for the entire journey.

Chapter I

INTRODUCTION

Vocabulary is vital to the success of students at all levels. From the first utterances and connections of sounds to words and words to meanings during childhood through graduate school entrance examinations, vocabulary is an essential component of communication and survival. If one desires to pursue education beyond high school, such as in a technical school, college, or university, the mastery of vocabulary is an important component. Such mastery of vocabulary is important both early in school or work as well as later in education as well as within any vocation. The need for excellence in vocabulary is evident in entrance examinations, placement testing, and course execution. In any vocation, the understanding of pertinent terminologies, such as tools or procedures, is crucial to execution and success.

The problem concerning vocabulary acquisition is a lack of definite methods. As evidenced by the Georgia Department of Education (2015), there is no best way for students to learn vocabulary. Instead of clear direction, a display of option is presented. Additionally, Marzano (2010) and Beck, McKeown, and Kucan (2013) all recommend a variety of methods for vocabulary education as opposed to a best method. With some sciences and fields there is a best method indicated. For example, electricians learn how to wire a light switch without much variation. There is a code which is to be followed. Understandably students are not electrical circuits and teachers are not electricians,

however there remains no common ground from classroom to classroom as far as pedagogical practices are concerned. Thus, this study was conducted with the intent of the determination of a sole methodology for vocabulary mastery. The use of a kinesthetic activity was conducted in contrast to a more traditional practice; specifically, the use of modeling clay in vocabulary pedagogy was used along with the construction of sentences.

Graphic organizers, memory games, team activities, and technology are used routinely in schools for vocabulary mastery. Tactile or kinesthetic approaches are less evident in secondary schools. While there may not be as much research regarding kinesthetic pedagogy in vocabulary instruction, there is definitely a void in the presence of research regarding the use of modeling clay. Using clay to represent ideas and concepts in schools is not new, nor is using clay in a classroom environment (Hubbard, 1996). Furthermore, the use of modeling clay has proven successful in a few fields. Studies with younger children have had positive results (Chumark & Puncrebutr, 2016; House, 2007). House (2007) used clay to develop the understanding of artistic nomenclature related to clay itself. The terms included rudimentary words, and direct application with the clay, such as twist, roll, pinch, press, bend, and shape. House chose clay as students in the younger grades were likely to, and did, use descriptive language in such a setting. At the collegiate level, Kooloos, Schepens-Franke, Bergman, Donders, and Vorstenbosch (2014) employed clay in an anatomy class to create representations of anatomical procedures. This use of clay was employed in juxtaposition to videos of the procedure as well as the procedure itself. The results of the study were positive as regards clay. As one might expect, the students who actually performed the anatomical

procedure scored the highest, but the use of clay did produce higher results than the use of film. These results are worthy of note as there are times in education when an actual application of theory is not possible. If a social studies teacher desired to recreate a battle scene in clay it may prove more useful and have details better understood by students than simply watching a film about the battle.

The ideas presented by Kooloos, Schepens-Franke, Bergman, Donders, and Vorstenbosch (2014), House (2007), and Hubbard (1996) were used to formulate a study using clay as the treatment methodology. Despite the lack of extant research the study was able to draw sound conclusions focusing on kinesthetic activity and referenced data from Dale (1947). To further support the need and structure of the study, the application of the dual coding theory, from the works of Paivio, is used (Erfani, 2012; Moody et al., 2018; Rupley, Paige, Rasinski, & Slough, 2015).

Statement of the Problem

Educators in elementary school classrooms utilize multiple instructional strategies for teaching vocabulary. However, at the secondary school level and collegiate level, direct vocabulary instruction is not undertaken as readily. Nomenclature for courses in high school and college may simply be introduced by the instructor or left for students to discover within their materials. Students, for the most part, are expected to master the definitions and usage of vocabulary words on their own.

Although vocabulary instruction may not be occurring as readily in upper grades the Georgia Department of Education is aware of the need for such pedagogy. The website for the Georgia Department of Education (2015) contains a vocabulary strategy toolbox including a variety of tools for educators to use in their classrooms. There are

many learning strategies presented with varying classroom activities and approaches to vocabulary acquisition.

One of these tools, for example, is the Knowledge Rating Scale, which is a graphic organizer requiring students to rate their understanding of the words presented, write information learned about the words, and provide definitions using their own wording. The Frayer model, which students use to learn words using definitions, facts, examples, and non-examples is also included in the online Georgia toolbox. The Frayer model's non-example component is a unique in comparison to other pedagogical strategies provided. The vocabulary strategies toolbox presents another method of learning nomenclature called Making Meaning. This method of vocabulary acquisition uses context clues from the textbook, article, webpage, or other sources to have students arrive at a definition on their own. K.I.M. is yet another strategy that requires students to delve deeper into words than a simple definition. With K.I.M. students write out key terms or ideas (K), then include information about the word (I), and lastly provide a memory clue (M). This has also been varied to include the (I) as an illustration.

Georgia teachers or students can choose from and utilize more than 20 pedagogical approaches presented in the vocabulary strategies toolbox (Georgia Department of Education, 2015). These may be used to either learn new vocabulary words or strengthen words not known completely. Most of the options presented tend to deal with the organization of the words and what is already understood about the words. Some of the activities rely upon contextual clues. Contextual clue vocabulary activities are not as reliable as other pedagogical methods. Creation of a definition from contextual clues is not as sound as referencing a dictionary, glossary, or textbook for an actual

definition. While using context clues may assist some students in ascertaining the meaning of the word or an approximation of the word's definition, some students need a structured learning methodology (Behlol & Kaini, 2011).

Ali, Mukundan, Baki, and Ayub (2012) while determining that computer involvement in the vocabulary instruction was effective, simultaneously investigated context clues and dictionary use. Beyond successful use of the computer program (Computer Assisted Language Learning), vocabulary acquisition through inferential methods were less effective. A key component to the ineffectiveness of the use of context clues was the inability of students to make a determination of existing clues. For students to construct a meaning within the context they must be able to discern what is present to extrapolate from to form a definition.

Another noteworthy consideration is the lack of word use when ascertaining the meaning of the word. Words are most often used in sentences. Most of the vocabulary learning tools did not include the use of the words within sentences.

Thus, the Georgia Department of Education has provided a number of vocabulary organizers, some learning strategies with context clues, and a lack of teaching through the use of sentences. Furthermore, the Georgia Department of Education (2015) does not recommend any specific methodologies for teaching vocabulary in courses. The result is that educators choose strategies they are familiar with or that they think will keep students engaged. Foil and Alber (2002) argue that understanding vocabulary is a necessary subskill for mastery of a language, and by extrapolation the topic at hand. Educators must decide what they think will work based upon their previous experience with one of the pedagogical methods presented. Another potential basis for deciding

what method to use may recommendations from peers, department heads, or administrators. The description of some methods may lead a teacher to assume they will be engaging with a great deal of kinesthetic activities. What the Georgia Department of Education offers is a toolbox with suggestions for implementation.

What could have been provided by the Georgia Department of Education are recommendations based upon learning styles, disciplines, gender, or even grade levels. There could be suggestions based upon the effectiveness in the various disciplines. For example, one toolbox method could have been found to work well in math, another in ELA or social studies. There could be recommendations for the education of those with special needs with specific disabilities or students in a gifted program. If possible, recommendations could have been given based upon grade level or at the very least methods for educating grade school, middle school, and then high school. There could even be recommendations using time as an integral factor or available resources. In addition to a lack of recommendations regarding learning styles, there are no comments on multiple intelligences theory, dual coding, or other pedagogical strategies.

Concern over the lack of recommendations accompanying the toolbox from the Georgia Department of Education and details concerning pedagogical options has led to the design and execution of this study. With over twenty different strategies on display for educators in Georgia to use in the classroom, this study was designed to ascertain the use of a kinesthetic teaching model versus a more traditional approach. The study does not entail the use of organizers or context clues. This study employed methods of vocabulary instruction and, through a mixed methods approach, ascertained the effectiveness of specific pedagogical methodologies.

Theoretical Framework

The theoretical framework of the study included Dale's (1947) experiential pyramid, Hubbard's approach to the use of clay (1996), and the dual coding theory of Paivio which was employed in the area of science vocabulary with positive results (Kortz, Grenga, & Smay, 2017; Rupley et al., 2015). The use of learning styles and focus upon them is paramount to both the design and execution of the study. The study also includes consultation of multiple intelligences theories from Gardner (1983).

The study focuses primarily upon the use of Dale's (1947) concept of a contrived experience as a background for the study. With the intention of using clay in the classroom, a construct was needed to support the use of clay. Thus Dale (1947) was included to form a foundation that justified the time and effort in application of kinesthetic learning with clay. The students in the study actually created items in the classroom which mimic microscopic biological entities. The use of hands directly employs learning style theories, multiple intelligences theory, and dual coding theory.

Using clay for the study engages the visual and kinesthetic aspects of the students in a classroom setting. The observable and measured data from the study include surveys, assessments, and teacher input. With the dual coding theory (DCT) of Paivio employing visual and verbal aspects (Erfani, 2012) and the concept of contrived experiences from Dale (1947), the study is firmly grounded in kinesthetic classroom activity. Although there may exist a variety of descriptions of what is entailed in kinesthetic activity, Gardner's (1983) theory of multiple intelligences was also researched and included as the foundation for bodily movement in the classroom.

Educational methods of instruction vary greatly from the elementary levels to the secondary levels as evidenced by classroom disciplines, educational tools employed, use of computers and technology, and variety in assessments and student demonstration of mastery. Methods of vocabulary instruction, as chiefly noted on the Georgia Department of Education (2015) website, vary widely as well. The intention of the study was to determine the viability of using modeling clay in vocabulary acquisition. The study was designed using modeling clay procedures from Hubbard (1996). The reasoning for the selection of Hubbard's method was simply the lack of discovery of any other applications. The procedures were duplicated and used in a high school biology classroom. The reasons for choosing science was simply that the words included in the study could be unique likely unknown to the students. Biology was chosen because every public high school in Georgia teaches biology and accessing schools for the study would prove easier and results would be more applicable.

While a more pragmatic approach was used to determine the effectiveness with clay there remained a need to choose a control group approach to learning vocabulary. Writing sentences with the words was done in contrast. Writing sentences was employed as a more traditional approach to vocabulary instruction and use. Thus, the study used both a traditional scholastic approach, with the writing of sentences, and a creative kinesthetic approach, with the use of clay, to determine the effectiveness of modeling clay pedagogy.

The use of kinesthetic methodologies in the classroom allows analysis of study results with respect to multiple intelligences theory, dual coding, and learning styles. The

study also allowed a reasonable comparison between kinesthetic methodologies and practices classified as visual and more symbolic in nature.

The intent of the study remained to determine the best method of instruction for vocabulary acquisition. The study began the process with the pitting of kinesthetic learning against other methods. The value of inclusion of physical methodologies in the classroom could be of great use in the field of vocabulary acquisition. Looking beyond visual and auditory learning at kinesthetic learning with experiences created for students may also provide deeper insights concerning dual coding and multiple intelligences theories.

Research Questions

This study design was an explanatory sequential mixed methods design driven by three research questions that are quantitative and qualitative in nature. The quantitative strand of data, which addressed the first and second research questions, was more heavily weighted than the qualitative data strands, which was used to address the last question. The reasoning behind the stress of the quantitative strand is found within the research questions and the pragmatic viewpoint of the design. While determination of a pedagogical method may be assessed in various ways, the use of written examinations provides more of an objective view than an interview might. The first research question is best answered with test results. The supplemental second and third research questions were asked to elicit additional data in response to how the participating students and teachers felt about the study itself and any benefits or challenges in the study. The second and third research questions did not provide information about the success of the pedagogical methodology employed. With the proposed design, the quantitative data

collection occurred prior to the qualitative data collection (Creswell & Plano Clark, 2011). The research questions were as follows:

1. Is there a difference in vocabulary test scores between students who study biology vocabulary using modeling clay and those who do not use clay?
2. What are students' and teachers' perceptions regarding the use of modeling clay for biology vocabulary acquisition?
3. What are the challenges and benefits of using modeling clay for biology vocabulary acquisition in the classroom?

The data to answer the first question came from the test results of high school biology students. The data for the second research question was obtained from the same high school biology students in the form of a Likert-style survey. The participating teachers provided information, via a series of interviews, in response to the second and third research questions.

The use of modeling clay was used as the experimental treatment in the study while the writing of sentences was used with the control group. These two activities comprised the contrasting vocabulary acquisition methods for the entire study. The treatment group was referred to as Group C where the C indicates the use of clay. The control group was referred to as Group S as sentences were written by the student in the study.

Methods

The choice of research design was based upon the dissection and best possible procedures for extraction of data which would come from the research questions. For example, assessments taken prior to and after the classroom lessons seemed to be an

effective way to answer question one. Whereas surveys and interviews were chosen to obtain answers to the more subjective research questions. Inspection of Creswell's (2014) designs led to use of the explanatory sequential mixed methods design. This design answers not only the quantitative assessment structure but the potential justification of results through qualitative research (Creswell, 2014). The additional information gleaned from surveys and interviews was used to compare feedback and suggest new approaches for future experimentation.

This study was conducted at multiple locations and included two cycles. Each participating school had two units of the biology curriculum to complete: cells and genetics. Furthermore, per IRB instruction, the classes contained both the clay usage and the sentence writing. Thus, each class had half as the control group, while the other half of the class conducted the treatment activity.

The order of events in the classroom was a pretest, then the vocabulary activity (modeling with clay or writing sentences), followed by a posttest, retention test, and survey. This was concluded with the participating teachers taking part in an interview. Then the halves of the class switched and the genetics unit was undertaken by the students. Thus, according to the design, every class in each school had a quantitative testing phase, then the experiment, then surveys followed by interviews. Once this cycle is completed with the cells unit in biology, it will be repeated for the genetics unit of the curriculum.

Significance of the Study

The significance of the study lies within two main areas. The first area of concern was the effectiveness in using modeling clay in the classroom. Focus was placed upon

how the instructors planned for the use of clay, managed their classes to facilitate the use of clay, and any other issues with clay as a unique learning medium. This study's kinesthetic approach centered around the use of modeling clay. Although there have been studies of using clay in elementary classrooms and in college-level anatomy classrooms, there are no discovered studies of this teaching method in high school classrooms (Chumark & Puncrebutr, 2016; House, 2007; Kooloos et al., 2014). Thus, the study has provided a starting point for subsequent studies using clay as an educational tool for vocabulary instruction.

Secondly, the analysis of the data using clay as a kinesthetic tool in contrast to writing sentences has led to insights regarding the success of kinesthetic learning and the impact of such learning on gender. Specifically, Group C worked with the clay and Group S underwent a more traditional approach to learning vocabulary. The direct comparison of the two proved interesting and also provided input regarding gender and kinesthetic vocabulary acquisition. The findings were in accord with other studies involving kinesthetic, however, none included the use of clay.

Definitions of Terms

Classroom management. Classroom management implies the sound ability to establish and maintain a learning environment. The concern with this study is ensuring the added factor of modeling clay and use of unfamiliar procedures is met with control over the student body.

Clay creation. A clay creation is a representation of a word or phrase done with modeling clay. Each part of the creation will be labeled independently. The entire creation will have an overall label. A clay creation is not a work of art. For example, in making a clay

creation that defines the life cycle of a tree, one might mold a small piece of clay into the shape of a seed and then write "seed" on a small piece of manila folder and stick it in the clay. Next to that, clay shaped into a small tree may be labeled "sapling". Following to the right, one could make a larger tree and label it "tree." To the right of the tree one could make a tree with just bare branches and label it "dead tree." Lastly, one could roll out a long, thin line of clay and place an arrow on the right side and label it "time". The overall label would be "The life cycle of a tree." In this example, each piece of clay is labeled and there is an overall label. The arrow denotes the passage of time.

Control group. The control group refers to the students who wrote sentences using the biology vocabulary terms as part of the study. Students in this group were pretested, post tested, and took retention tests. The data was analyzed and compared with that of the treatment group. This group is referred to as Group S or control group throughout the study.

Explanatory sequential mixed methods design. The explanatory sequential mixed methods design of this study is a mixed-methods design wherein data will be gathered from quantitative testing and from qualitative survey and interview. However, in this study the entire cycle will repeat. The repetition will be centered on two biology curriculum units each with the same steps, but different instruments and a transposed body of students. (Creswell, J. W., & Plano Clark, V. L., 2011).

High school biology cells unit. The study was based upon the use, testing, and discussion of biology terminology related to specific units in the biology curriculum. The cells unit refers to the portion of the study focused on the use of twenty words concerning cells and

their anatomy and function. This unit was completed prior to the genetics unit in the study. A complete list of the biology cells unit terms can be found in Appendix A.

High school biology class. For purposes of the study, a high school biology class refers to Georgia public school high school students in a regular or honors classroom in the ninth or tenth year of schooling.

High school biology genetics unit. The study included the completion of specific pedagogical exercises with two sets of vocabulary terms. The genetics unit is based upon the use, testing, and discussion of biology terminology related to the genetics portion of the biology curriculum. This unit was completed after to the cells unit in the study. A complete list of the genetics terms can be found in Appendix B.

Hypoallergenic modeling clay. Hypoallergenic modeling clay is the primary tool used in the study. Hypoallergenic refers to the lack of allergens within or the non-toxic nature of, the clay. In the study, the participating students will shape (with their own hands) objects that will be included in a creation representing the vocabulary word. Within this proposal, hypoallergenic modeling clay may be referred to as modeling clay or clay.

Kinesthetic. The term kinesthetic, from kinesthesia, meaning the sensation of position, movement, or tension of body parts (Neufeldt, V., 1997) is closer to the use herein than the descriptions of Bip being tossed around in a train from Gardner's Frames of Mind (1983). The term describes not the overall use and mastery of the body or a bodily-kinesthetic intelligence, but simply the use of hands for physical manipulation of the learning tool during vocabulary instruction.

Mirror questions. Mirror questions refer to student survey questions containing similar content but worded differently within the two study surveys. In this study there is a

Group C and a Group S. Both groups have a survey for the participants and each group member must take a survey when they are done with the classroom portion of the study. Group C and Group S have different surveys. For example, the survey question in Group C may state: Did you like working with clay? A mirror question for Group S would be: Did you like writing sentences? 24 of the 25 questions in the survey for Group S had mirror questions in the survey for Group C.

Retention test. The study will make use of three sets of testing. While the testing includes pretests and posttests, there will also be a third round of testing to take place during the week following completion of posttests and surveys. This final use of the test is referred to as a retention test.

Sentence pedagogy. Throughout this study the students will with make clay creations or write sentences. The control group will write sentences in contrast to those working with clay. Writing sentences implies the student will write three sentences with each biology vocabulary word demonstrating meaning or an understanding of the word. For example, a student would write "The mitochondria provide energy for the rest of the cell," as opposed to "I like studying mitochondria."

Treatment group. The study contains two groups of students in each classroom. Data was gathered from both the control group and the treatment group and then analyzed and compared. In this study, the treatment group refers to the students who worked with modeling clay to create definitions of biology terms. This group is referred to as Group C or the treatment group throughout the study.

Limitations

Limitations for the study included sampling, participants, instrumentation, time, and subjects being addressed. The following limitations are of concern for reasons of internal validity of the study itself. Additionally, the participants and sample size also serve to limit the generalization of the study. While the limitations of generalization of the results from this particular study may prove to be valid, the design of the study may still prove noteworthy and other studies may be conducted in a similar fashion.

Convenience sampling was used to generate participants. A local Regional Educational Service Agency (RESA) was the primary resource for locating and soliciting study participants. The use of the researcher's local RESA may have limited some aspects of state-wide demographics, nevertheless it provided a solid foundation for assessing Whites, Blacks, males, females, and a lower socioeconomic demographic which is typical in the Southern Georgia. The demographics utilized in the study did provide a sound platform for dissemination within Georgia or other similar populations across the United States.

Student participation was dictated by the rosters of the teachers who were willing to participate in the study. Analysis of the composition of the classes was an essential part of the study and the results included a breakdown by gender. Worthy of note was the unwillingness of administrations, in particular some principals and superintendents, to partake in the study. The number of teachers willing to take part in this study actually exceeded those who conducted the study in their classrooms.. There were three superintendents who gave permission for the study to take place within their high schools.

Due to the novel nature of the study, all instruments were created especially for this study. There was no background history to gauge results from this study upon. Thus the instruments used were all analyzed comparatively within the study. The design of the study included a genetics unit and a cells unit and thus strengthened results through repetition. The assessment instruments were used in five classrooms, three times, with Group C and Group S. Dissemination and collection of various components and scheduling of interviews was arranged and coordinated with the teachers directly after approval from both superintendents and principals. Teachers were in communication for the study via phone, text, and email.

Participating teachers were veterans in teaching science and, more specifically, biology instruction. Administration referred the teachers as having no classroom management issues. Furthermore, the instructors were recommended by their principals, and one by her department head. The use of examples, multiple workstations, and setting targets for some students assisted in limiting time as an area of concern.

The study only addresses high school biology as outlined by the Georgia Department of Education. The study design and procedures may be extrapolated and used in other high school science classes or other disciplines, but the data only includes conclusions regarding high school biology. The findings, particularly those relating to kinesthetic and gender may serve as a springboard for future studies.

The study delimitations included the objectives of the study, the discipline taught, the methodology used within the experiment, and the design of the study. The study design was chosen not only for its scientific, pragmatic approach but also from the desire to include qualitative aspects that may shape similar future studies. The goal has never

been to stop after the execution of this study. Thus, the inclusion of qualitative analysis was vital for the success of the study.

Present and previous personal experience using clay in teaching had shown success, yet there remains little documentation to justify the use of clay. The transitions for the use of clay in other languages and all levels of education are seamless. A remaining question from the study could be: Why has no one previously investigated this approach?

For logistical reasons, only high school biology was selected as the content for the study. There may be other topics which could have been used, but an isolated science nomenclature in a common topic was deemed the best choice. Once future researchers review the data contained herein, other science classes may be chosen. Further studies could be conducted vertically at any level of education, from elementary school to college, and horizontally across the disciplines in high school including math, social studies, English, or other high school curricula.

Organization of the Study

The investigation into the use of modeling clay in high school biology is presented within a traditional framework. The first of five chapters includes the introduction to the topic, a summarized explanation of the study, the topic, and the ideas behind the particular approach to the study. The first chapter includes an overview of the design of the study. The second chapter discusses the literature pertaining to the topic of the study. This chapter also includes commentary and how the literature relates to the study at hand. The third chapter, entitled methodology, breaks down the explanatory sequential mixed methods design employed for the study. The instruments used in the

study are explained in Chapter 3 along with the sequencing of events in the study. The research questions are also discussed as well as the methods that were used to collect and analyze data to provide answers to them. Chapter 4 details the results and provides a number of tables to explain and highlight the results obtained. The fifth and final chapter interprets the results presented in the previous chapter and comments upon the processes used in the study with recommendations for the future studies. Finally, the chapter provides information on limitations and internal validity as well as provide recommendations for generalization and dissemination of the study.

Chapter II

REVIEW OF THE LITERATURE

The study focused upon the acquisition of science vocabulary. Nearly every field has its own nomenclature and many fields have their own training programs with unique terms as well. For example, there is a distinct set of terms used to describe the parts and tools in the automotive field; likewise, there are anatomical terms and vocabulary specific to the medical field. Even the military and the field of education have vocabulary unique to their societal niche with dozens, if not hundreds, of acronyms added on top. Vocabulary is vital. According to Merriam-Webster (N.d.) there are nearly half a million words in the English language with approximately 800 to 1,000 words added annually.

Scholastic Aptitude Tests (SAT) remain an entrance gateway for college-hopeful high school students. These assessments include a battery of vocabulary questions. Speyer (2004) discusses the rise in SAT scores and potential reasons for this rise. Speyer (2004) details four main reasons for increases of SAT scores in America. With such huge numbers in applicant pools, Speyer (2004) notes the benefits of having a simple qualifier, like a numerical SAT score. That is, colleges can simply filter their applicants by looking at one point: the SAT score. In addition to looking at the SAT scores, colleges and universities frequently publish the SAT range of their accepted students. The advertised ranges may curtail applicants who are not of the caliber typically admitted to the university or college or attract those who are more ideally suited to the institution.

Speyer (2004) posits the following four factors which may be responsible for the increases in SAT scores. The first is to say that today's children, or at least some of them, are smarter. The second point is claiming children read more today than earlier generations. Another possible reason for increase in SAT scores is the ability of students to understand arguments more rapidly. Exposure to the internet and mankind's cumulative data online may be a factor regarding this third point. After all, there are a multitude of study guides, cheat sheets, and tips for sale to allow one to better understand the formatting of tests, and include practice or mock tests, like the SAT. A final point Speyer (2004) makes is the broadening vocabularies of students today. The increase of broadening vocabularies may be related to internet exposure and study guides as well. What is lacking within the article is any pedagogical method for vocabulary acquisition. So, while more expansive vocabularies exist among upcoming college bound Americans, there is no offer of how this increase came to be.

Although Speyer limits his discussion to the SAT and college entrance (2004), it would not be a far reach to address and liken his conjectures to the Miller Analogies Test (MAT) and Graduate Record Examination (GRE) and the reliance upon definitions of broader vocabularies. The obvious distinction would be the fact that the latter two examinations are used at the graduate level, not the undergraduate level. There would also be an assumption wherein some of the specialized, or field related nomenclature, would already have been mastered by students at the undergraduate level. Regardless of the assessment type or timing, vocabulary pedagogy needs to be investigated.

A cursory examination of data from the National Assessment of Educational Progress (NAEP) indicated there has been little success with vocabulary instruction (U.S.

Department of Education, 2013). Their data addressed 4th, 8th, and 12th grade students and included recognition of the words fascinating, intently, and precedent respectively. Although in each case 75 to 79% of the students recognized the definitions of these words, there was only a 1% growth from 2011 at the 4th and 8th grade levels. More notably, at the 12th grade level there has been no increase since 2009. Females scored higher than males in 4th and 8th grade, but by 12th grade both genders' scores were virtually even. And, as with Speyer (2004), there is no indication of pedagogical methods used to teach or acquire new vocabulary. Understandably, the government agencies report summative data and are not necessarily involved in the classroom activities or pedagogical procedures employed. The data, nevertheless, is disconcerting.

Typically, vocabulary, and its mastery, is viewed as taking place in the lower grades and the English classroom, but beyond the English and reading classrooms, some researchers have been focused on how to learn vocabulary in the hard sciences.

Investigations beyond the English classroom include topics such as biology, chemistry, and physics (Seddigh & Shokrpur, 2012; Young 2005). Research into hard sciences may be unique as they include specific nomenclature providing an opportunity for untainted results. Unless students are reading texts or articles in the subject, it is likely they have never encountered some of the words before. This new exposure to words allows researchers to assess methodologies with a greater internal validity as there exists a sense of purity related to learning words anew. Although some vocabulary may have multiple meanings, the students learned the definition pertinent to the subject at hand. For example, when a student in chemistry learns the word titration, it is likely a word never before seen. However, when a student in chemistry learns the word solution,

the known definition likely relates to answers to problems in math or in life, as opposed to understanding the components of liquid compounds.

The ability to isolate terms and use nomenclature not encountered before was a factor in deciding the topic of the study. This study uses a hard science; more specifically biology with nomenclature extracted from the unit on cells and the unit on genetics. Not only is biology taught in every public high school in Georgia, but the content is also based upon the same standards. Although the use of less common words, and words from a specific field of study seems justified, the methodology or methodologies of instruction remain in question. The purpose of the study was to search out the best pedagogical procedure or at the very least, a better category to pursue to ensure effective vocabulary assimilation.

Data Input Processing

While construction of the study was centered upon learning styles and multiple intelligences theories, also included was consideration of processing theories. A student knowing he or she is a visual learner implies they learn best using visual cues or lessons centered on vision. Paivio's dual coding theory (DCT) suggests learners receive information in more than one way. In other words, a student sees a word and the brain receives input through visual channels while also activating the brain through verbal channels. These are two distinct passages in the brain which contribute independently, yet simultaneously (Rupley et al., 2015). The notions of how students actually learn, while not within the scope of this study, bear heavily upon the study's design. The purpose of the study was to better understand pedagogical approaches, thus having a greater understanding of various theoretical avenues to frame lessons and actuate them

within the classroom was necessary. DCT is a theory with precepts related to learning styles, multiple intelligences, as well as research by Dale (1947) and Hubbard (1996). Dale (1947) and Hubbard (1996) approach learning from the aspect of what an educator can do in the classroom with students. DCT provides understanding of the brain and at what level learning takes place. The brain actually stimulates two separate pathways when learning is occurring. When the verbal pathway and the non-verbal pathway join together important connections for the student are made (Moody et al., 2018). Kortz et al. (2017) state the combination of the two pathways simply lead to a greater understanding then mere visual or verbal clues alone.

Kortz et al. (2017) conducted research to determine the comparative effectiveness of science textbooks. They discovered use of figures, numbers, charts, etc. were ineffective, per dual-coding theory, when figures were presented next to the text providing explanation. If numbers were on a different page they were not effective. For the dual coding to have been effective, the text, notes, and explanations needed to have been adjacent. Erfani (2012) conducted research which pitted learning with a text and picture against learning without pictures. This study was conducted with foreign students majoring in physics. The results, verified with a significant difference in *t-test* and mean scores between the control and treatment groups, clearly showed using pictures along with the text improves learning over text alone. This study verified dual-coding theory. Rupley et al. (2015) also discovered the use of text in concert with pictures is helpful to student learners. They also add, however, that the use of pictures must coordinate with the text and scaffolding must be employed successfully by educators. Simply adding photographs, charts, and diagrams without expertise does not enhance learning.

DCT also promotes the notion of transforming abstract ideas into a more concrete form (Moody et al., 2018). The study design was centered around science vocabulary, specifically biology. While mathematics may be entirely abstract at times, science constantly presents ideas which may also be considered abstract. Without viewing a cell through a microscope the notion of a cell is abstract. Genetics and the various combinations of offspring in any species may not be perceived as concrete either. Moody et al. (2018) stated the use of DCT in science is particularly valuable as it aids in bringing to light the more conceptual lessons.

An understanding of dual-coding theory enhanced the interpretation of the breadth of the study and use of the study's design. DCT includes the use of visual cues as well as verbal cues. Visual learning alone is not as effective (Kortz et al., 2015; Moody et al., 2018). This study has taken dual coding theory a step further by including the creation of clay models.

Experience and Symbolism

Searching for effective pedagogical methods have led to an understanding of various approaches from Dale (1947) which were used as a foundation for this study. One underlying concept was that when actual experiences cannot be duplicated in the classroom, experiences approximating real life or the actual event should be created or recreated as accurately as possible. He created a scale from learning situations extending from real-life experiences to reading about a subject, each scenario moving further from the actual experience to the use of symbols.

The effectiveness of language, whether spoken or written, is based upon the understanding of symbols. In English, 26 symbols make up the alphabet. These symbols

are used to create words and each word is a symbolic representation of an idea, concept, or thought. If one says a word about something which is not present the concepts exchanged between individuals relies upon their understanding of the word or the symbolism they each have for the word used. For example, if two individuals are talking about boats, their initial images may be very clear but not alike. As they continue discussing boats, or a particular boat, the symbol or the word for boat used more clearly represents the same boat or thing discussed. If the school was near a boatyard then the word boat would more accurately represent the boat. Furthermore, in a boatyard all an instructor would have to do is point and not even use the symbol, or the word boat. Dale's hierarchical concept of education and movement is pivotal to understanding more successful paths of education. Symbolism, including language, is more difficult to teach when contrasted with placing one's hands upon an object or tool and understanding its function. Experience is a superior method of education, but more often teachers in the classroom must rely upon vicarious learning and the use of symbols (Dale, 1947).

If the educational experience is more of an actual experience than something read about, the learning process may be remembered more accurately. In fact, the learning experience could be considered an experience rather than a lesson. Efforts made for the involvement of senses, or inclusion of more senses, may be a valid approach. The sense and sensation is part of the experience. The smelling of rain, the sight of smoke rising, the viewing the moon sitting behind the trees, the feeling of one's foot on the ground, the taste of chocolate, and the coolness of the water on your body as you dive, all are part of experiencing. Ideally, in a great lesson, there must be newness, an emotional tone, a sense of fulfillment, and a sense of personal achievement (Dale, 1947). For the lesson to

be most effective he included psychological aspects to the experience. Thus, the smell of rain or the taste of chocolate includes more than the sensory input. There is more than simple accumulation of data; the whole would be, in these situations, greater than the parts.

Student participation (i.e., concrete and purposeful experience) is the most valuable method of education. These experiences hold more reality as opposed to the vicarious learning through symbols (e.g., alphabets and numbers). The more symbolic the teaching, the less bearing and use it has for the student. For clarity, Dale (1947) created a pyramid which outlined his cone of experience. The methodology forming the basis (or base) of the pyramid (learning) is actual experience. Every pedagogical method employed above the base is less ideal. The cone of experience contains ten levels each with their own activities moving from an ideal experience to more and more vicarious instructional approaches. The first three levels of the cone include direct, purposeful experiences, then contrived experiences, and, on the third level, dramatic participation. These first three levels all include participation whereas the next five levels include observation. The contents of the middle levels are, in order, demonstration, field trips, exhibits, motion pictures, and finally radio, recordings, or still pictures. The upper two levels contain symbolism.

The contents of the level above concrete and purposeful experiences, which is the base of the pyramid, are "contrived experiences" (Dale, 1947, p. 38). Contrived experiences might include models, miniatures, mock-ups, even an old car or plane. The idea for the educator is to approximate actual events. While it may be ideal to visit a volcano to experience the sights, sounds, smells, it may not be possible for a number of

reasons, including safety. If one were to teach automotive repair the acquisition of damaged vehicles may not prove to be difficult and thus the lesson would be an actual experience. However, one may simulate an accident and engage in mock repairs if such wreck did not exist. Contrived experiences could include building models of volcanoes or the use of wooden soapbox cars. The intention is to provide an experience as close to the actual experience as possible for the students to learn. Another consideration for the use of mock-ups or models is the instructional control over time and place. Teachers may not be able to wait for a volcanic eruption or an auto accident involving right rear damage. Furthermore, a trip to Hawaii to view volcanos may simply not be possible. Simulation of these events in the classroom may be more effective.

Another step up on the cone of experience is dramatic participation. Studying Dale's cone of experience, the distinction between being a dramatic participant and a member of the audience is more clearly seen. Observation of someone walking by, witnessing an accident, or seeing a commercial does not compare in wholeness to one's self walking around downtown, being in an accident, or being in a commercial. Dale (1947) states, "a stirring experience is not easily forgotten," (p. 103). Furthermore, there are numerous inherent values in dramatization, not limited to diction, vocal control, body control, an understanding of the character, and a connection with the author. Within a classroom where dramatic participation is being used a student must present to his peers the events through actions and words. The students could be involved with the writing of the script and create dialogue for themselves and others. The students might create props for their presentation. And students typically rehearse and memorize. The acting and playing a role is an experience which may include other aspects beyond the lesson or

what is portrayed within the skit or play. Some students could harbor concerns with being on a stage, expression before peers, difficulty in conjuring up emotions, or simply mustering a voice loud enough to be heard. The use of dramatization can add an emphatic lesson to nearly any classroom.

The cone of experience continues upward with the use of demonstrations. Science demonstrations occur with great frequency in laboratories and before classrooms. In addition to typical demonstrations in the discipline of science, foreign language, social studies, and mathematics are included. Some demonstrations involve student participation, but for the majority of students, demonstration represents the first level of observation. Even when students are involved in a demonstration the demonstration is a model representing an actual event and not an event one might experience in the world. On the cone of experience, demonstrations occur as the first level beyond the initial levels of experience or participation (Dale, 1947).

Continuing up the cone of experience, the next level includes field trips. Whereas a demonstration has students in the classroom or laboratory, a field trip implies students are mobile and able to observe events or species in a more natural environment. Whether the field trip takes place with a natural or manufactured setting the observation is designed to educate and possibly entertain. For example, a field trip in Georgia may easily include a trip to a cotton gin or a peanut processing plant. A guided tour through either facility is observational in nature. The students are not farming, not transporting the product, nor are they involved in the process directly, but they see directly how product development occurs in the world. Such observation is a type of experience and may generate questions, stimulate further learning, and lead to future mock-ups or models

being created. Despite the fact that learning on field trips is moving further from actual experiences for the students, observation happening in the world is more beneficial than observation taking place in the classroom.

Beyond demonstrations, which are focused and poignant, and field trips, which lead students into the community, the next level involves motion pictures. Motion pictures allow students to gain more insight regarding actions such as knitting or building a machine part. Where a photograph may prove valuable in understanding what woven cloth is, a short film showing the action of weaving cloth is extensively more valuable. Showing a film can teach one in a manner not dissimilar to a demonstration or actual hands on experience. While film obviously lacks an array of senses, it necessarily includes vision. Most films include sound composed of dialogue, ambient sounds, and even a soundtrack. While films and videos do include sight and sound, they remain further removed from the actual world where smell, motion, and other senses reside, leaving one a limited observer. Observation, of course, does not entail the use of the hands which would be the most purposeful and most valuable learning experience.

The cone of experience continues with still images including photographs, illustrations, and projected slides. The significant difference between all other modes of learning and the use of images, as well as the use of radio and recordings, is the number of senses used being limited to one. With photographs the obvious sense is sight and regarding radio and recordings the sense employed is hearing. The later chapters in Dale's book involve methodologies with fewer data input and call upon the student to assume a greater understanding. Moving further from the bottom level of the pyramid involves fewer direct, purposeful experiences. While the use of photographs may keenly

incorporate the use of vision, and radio employs auditory skills, actual experiences at the bottom of the pyramid may evoke countless senses. Additionally, the second and third levels, containing contrived experiences and dramatic enactment respectively, also employ a number of senses (Dale, 1947).

At the top of the cone of experience, which contains the last two levels, is symbolism. Language contains written and spoken words. The upper or symbolic end of the cone of experience relates directly to DCT (Erfani, 2012). With the lack of experience and increase in symbolism the need for more sensory input is evident. With DCT there exist two pathways of input for the brain. There is no or limited experience needed in the physical universe to understand some things through pure symbolism. Spoken language requires one understand words and their meanings. Written language also requires an understanding of vocabulary. Learning vicariously with symbols happens in one of two ways. The first way is through symbols directly as with definitions or mathematics. The second manner is understanding deductions from the symbols as in stories or lessons.

The concepts of symbolism and distancing it from actual experience on the cone of experience relates directly to discourse presented by both David Hume and Immanuel Kant. Hume and Kant both proposed synthetic knowledge (which Kant referred to as a priori) exists independent of experience (cf. a posteriori). The typical examples of such synthetic knowledge are mathematics and geometry. Also included are deduction and logic. Once concepts, such as those in mathematics, are learned, their use falls outside of the world of experience. For example, once one has mastered the concept of the quantity known as two it does not matter if one is counting marbles, pennies, or people (Russell,

1945). Vocabulary is at the top of the cone of experience while the most meaningful experiences for the student reside towards the bottom.

One mystery in student learning was the inconsistency of memory. Often, remembering is not as fruitful as planned or anticipated. The mind sometimes recalls things a person had no intention of retaining, yet fails to retain other things despite every effort spent (Dale, 1947). Motivation and intention are factors having influence upon the most effective learning when incorporated in the design of the instruction. The cone of experience focuses on the impact of experience of events leading to a more solid foundation of education. Students, using experience, observe and obtain more data than learning via symbols. Even motivation and intention may be more prominent within experience than within reading. Words are better recalled when made useable. If an experiment in a science lab includes the use of test tubes or beakers, students will be more likely to recall the name of the test tube or beaker than if the student merely reads about laboratory glassware. The doing may link stronger recall than higher bands on the cone of experience.

Lessons must be memorable in some manner. It does not matter whether it was a mnemonic device, a startling picture, a shocking film clip, or some other means, but need to leave a lasting impression. According to his research, some students have said they could not explain why a particular class was memorable. Dale (1947) adds that we forget what is seemingly not important, what we don't see clearly in a lesson, and what we do not make use of outside of class. Thus, effective teaching must provide proper motivation, clear goals, and adequate use of the topic or lesson. Before students enter first grade there are 2,000 words learned and these mastered "through handling, seeing,

hearing, tasting, and talking with others (and before they learned to read) are never forgotten," (Dale, 1947, p. 16).

Based upon the concepts described in the cone of experience, the intention of the study was to join the conceptual understanding of words in vocabulary acquisition with a contrived experience. The contrived experience for the study used definitions and kinesthetic learning in a unique approach. The approach employed the use of modeling clay. The use of clay allowed the gap within the cone of experience to be bridged.

Vocabulary Pedagogy

Currently the Georgia Department of Education (2015) website has a Vocabulary Strategies Toolbox that presents more than 20 different methods and tools educators may use when teaching. A large portion of these feature graphic organizers and interactive learning along with brief descriptions or step-by-step instructions. Some explain how to help students visualize the words and make teacher observations more efficient. Despite the directions and descriptions, there is no recommendation for best use with specific subjects. Furthermore, many of the items posted are activities as opposed to pedagogical strategies (Georgia Department of Education, 2015). Educators are presented with a grab bag of options for their students but no recommendations as to when they should be used or statistics of success for the pedagogical models.

The application of pedagogical practices is therefore up to the educator concerning both choice of methodology and circumstances regarding application. While there are numerous methodologies including those on the Georgia Department of Education website and beyond for vocabulary instruction (Ali et al., 2012; Foil & Alber, 2002; Naeimi & Foo, 2015; Nilforoushan, 2012), none claim to be the only way or the

best way to teach new words. Educators research best practices then employ what they have found to achieve good results. What appears to drive most methods of vocabulary acquisition is finding ways to keep students engaged by creating booklets, charts, games, colored paper foldables, and other methods beyond memorization or repetition. The efforts to be engaging appear to outweigh the need for results.

Some of the strategies presented by the Georgia Department of Education include the Frayer Model, a vocabulary cluster graphic organizer, Own the Word graphic organizer, and other tools meant to help students make connections and display various facts about the word or the application of the meaning of the word. The site includes games such as P.O.S.E., which has students make up clues about the word relating to People, Objects, Settings, or Events, and Erasing Relay where students race each other in paraphrasing. Other strategies suggest using notebooks and journals that enable students to create their own lists of words mastered.

Looking further into the variety of pedagogical strategies for vocabulary acquisition, investigation into learning styles seems of great importance. When Pritchard (2014) defined learning styles the language he chose is not only subjective but based upon the student. For example, the learners "prefer to learn by listening" for auditory learners or "prefer to learn by doing" for kinesthetic learners. Pritchard adds that kinesthetic learners "enjoy physical activity" (2014, p. 50). The subjective nature of the claim, while expressive, lacks substantiation of scientific claims by research. Pritchard adds to his claims by stating research data indicating the overuse of one learning style is limiting and most people use multiple methods concurrently. Pritchard's analysis of educational tools and methods recommend a combination of learning styles and

approaches in the classroom. Although not discussed in as detailed a manner as Dale (1947), the variety of approaches supports the basic tenets creating the cone of experience.

A point worthy of commentary is the change in language usage in resources from Dale in 1947 to Pritchard in 2014. Whereas classroom activities are outlined by Dale using terms like direct and purposeful experiences, Pritchard (2014) uses more psychological terms such as intuitive, active, and reflexive. The terminology shift denotes a causality change from the teacher to the student. This is consistent with the earlier comments on Pritchard's definitions.

While maintaining the value of learning styles and using the word prefer in describing students' use of learning styles, Pritchard cautioned divulging the favored style to students. The reason for the hesitancy is a tendency for students to focus only on their preferred learning style. Pritchard promoted the development of all learning styles for all students (2014).

When considering a current focus in education, brain-based learning, the same diversified approach to learning applies. If one wishes to teach a standard or has a learning goal, pursuing various learning styles is beneficial to the brain as well. The brain should not be limited to one favored approach for optimum learning (Pritchard, 2014).

Nation (2015) says most of the research has concluded extensive reading is the best way to obtain vocabulary knowledge. While extensive reading is an approach, and quite possibly the best lifelong approach, it may not produce results fast enough for students in a specific course within a practical timeframe. Blachowicz and Fisher (2002)

described the learning of new vocabulary as a process wherein the understanding of a word is akin to a light which becomes brighter through repeated exposure and use. Similar to Nation (2015), Blachowicz and Fisher (2002) also promoted learning via reading. They even proposed a variety of approaches including reading strategies, literature-based reading instruction and learning words from context. Pedagogical practices also included linking words with similar meanings, using pictures and imagery, and morphemic analysis. Charts, diagrams, and mapping are discussed and detailed for use by educators in the text. An additional instructional component not seen in other reviewed materials was the use of puns, riddles, jokes, and wordplay. The authors include sketches of a girl drawing a picture of drapes as opposed to closing them and a satyr-like image of a boy attached to a cow with the word cowboy under it (Blachowicz & Fisher, 2002). The engagement of the students through the use of wordplay may or may not be at a higher level, but with wordplay the awareness is raised.

Despite the variety of approaches there is still lacking the methodology versus methodology comparison. The pertinent question of how to best teach the students the words within a course or in a grade using the most effective manner remains. In other words, the best pedagogical practice for mastering vocabulary is still unclear.

A student's rich vocabulary is evident in discussion and interviews, in puns, and in stating exactly what one wishes to say or write (Beck et al., 2013). Furthermore, if one is educated his or her vocabulary may be an indicator. One area of variation in vocabulary acquisition lies in the socioeconomic groups. When the first edition of Beck et al.'s (2013) book was written there was not much direct vocabulary instruction and ten years later, when the second edition was written, not a lot had changed. The book's

introduction included commentary stating there remained a lack of vocabulary instruction with students. There also remained a deficit or gap in vocabulary from younger years through upper academic years. There have been some improvements in basals regarding the contained vocabulary lessons. These changes were not viewed as impressive, but rather wanting (Beck et al., 2013).

Beck et al. (2013) do not necessarily promote traditional dictionary review of terms, brief reads, or matching exercises. Rather the authors prefer interactive, engaging, direct, and vigorous vocabulary pedagogy. The studies completed by the authors refer to primary grades and not students of secondary schools.

Vocabulary study does not need to be constantly connected to a textbook or be limited to a particular setting. Words may come from a specific context, but are then used and observed in other areas of life. This reinforces the authors' comments on vocabulary study being vigorous, engaging, and direct. An example of this may be as simple as using the science term nucleus when referring to a company president or a home office. Expounding further, the authors' offer noting the use of learning words orally and then learning them in written form. In fact, with variations in oral presentation and reception of vocabulary, there are far more words learned than in writing. When reading, students must actually read more, and with greater variety, than is done to adequately acquire and master new vocabulary. Thus, although there remain statistics on how much reading occurs, the growth due to reading may be overestimated.

Beck et al. (2013) discuss the need for robust instruction. They refer to activities beyond the classroom and include TV, film, books, and interactions such as at home. More rigorous vocabulary activities include tallying uses or observations of words, the

use of synonyms, antonyms, essays, grouping in morphemes, and descriptions. The keynote appears to be direct instruction of selected words and their use beyond definitions and sentence creation.

Marzano (2010) is convinced that direct vocabulary instruction is necessary in K-12 curricula. Not simply direct vocabulary instruction, but robust instruction. The design includes organizing vocabulary in clusters or words that have similar relevance. This juxtaposition allows concepts to be taught along with other words defined with evident connections between them. The mastery of definitions is not the only action being undertaken as use of the words in relative context may occur more readily. Comparison and contrasting of words, along with a building of mutual usage, occurs in sentence creation. Application of such sentences leads to understand cluster vocabulary or words having a common core idea.

The idea of key terms is not a foreign concept and is employed in this study with an understanding similar to Marzano's (2010) approach to vocabulary pedagogy. The twenty terms for the two units of the study are key terms found in biology textbooks and other common instructional materials forming a foundation for future studies in biology. Marzano (2010) includes over 2,800 basic words he considers to be vital for all students to become productive communicators in our society. The book also contains an additional collection of 5,000 plus terms, bringing the total to over 8,000. The method of learning the words does not involve the use of modeling clay but emphasizes direct instruction. Marzano's recognition of the need for direct instruction is bolstered by the gap in academic performance citing a lack of mastering vocabulary in standardized tests.

Additionally, Marzano (2010) makes reference to the numerous words composing education up to the secondary level. A legitimate question could be posed asking which vocabulary words should be taught directly and which words students will glean through discourse at home, at school, socially, and by other means such as songs, reading, and the web. Vocabulary mastery, although recognized as vital, cannot be done through direct instruction as there are tens of thousands of words to master. Thus, the Marzano text focuses on over 8,000 basic words. Marzano groups words as clusters. This clustering of words enables educators to share common themes and similar concepts. Some of the clusters, or super clusters, include words listed under more scientific groupings such as the following: Light and Darkness; Chemicals and Matter; Life, Death, and Survival. Although none of the vocabulary terms from the study are included in Marzano's listings, the same grouping concept is evident.

Throughout the text a variety of instructional methods for the educators are detailed. The methods of instruction recommended include Venn diagrams, double bubble mapping, the use of sentences with prompts, comparison matrices, metaphors and analogies, and classification. Neither the results of nor the benefits of one method over another are listed (Marzano, 2010).

Kinesthetic Learning and the Use of Clay

Dale (1947) does not mention the use of clay, but Hubbard (1996) does at length. The purpose behind using clay is based upon the fact that photographs and sketches may assist with increasing reality for students; "the printed page and the spoken word are not a substitute for a tractor if he's studying about tractors" (Hubbard, 1996, p. 43). Clay manipulation is kinesthetic learning and fulfills a need that Dale (1947) called having

experience with the words. If one considers a number being a symbol, let us consider two again. The symbol for two, 2, is abstract or symbolic. If a student uses clay to form a 2 then the symbol has more reality, and using the hands to make the symbol has more reality and an experience to accompany it. The use of clay will involve the actual creation of a form and then labeling of the form created (Hubbard, 1996).

Research from the 1970s supported Dale's theories about hands-on learning as tactile learners (Dunn & Dunn, 2005). Kinesthetic learning was often referred to as including the entire body, such as sports or dance. However, tactile learning involved just the hands. With either method, the learning was more effective.

As noted by his hierarchical cone of experience pyramid, Dale (1947) noted that doing or experiencing was a better method of education than the use of symbols. In other words, students will learn and retain information more effectively if they do things or go through an experience. Kinesthetic or tactile methods are more effective or successful than merely visual or auditory methods (Dunn & Dunn, 2005). In either Dale's or Dunn and Dunn's approach, the use of actual objects or manipulatives is an entirely separate encounter from kinesthetic intelligence (Gardner, 1983).

Gardner's concepts of intelligence are not akin to kinesthetic application in the classroom. The ability to function and perceive on various levels or have multiple IQ's, including being body smart or having kinesthetic intelligence, is not the same as the use of manipulatives or physical activities in the classroom. The difference is not merely in the classroom activities, but the use of the body itself. True the cerebellum is the portion of the brain responsible for balance and coordination, but for some reason some of us have better success than others. Some are able to pick up a ball and play a sport easily.

Others may have difficulty in mastering any sport. Gardner (1983) refers to dancers and others who seem to have the ability to execute perfect control over their bodies. The precipitate idea is the body possesses an intelligence. Pursuant to this concept is the dismissal of the concept that what the body does, or is capable of doing, is no less valuable or worthy of respect than what the mind allows one to accomplish. Considering the activities of sports, one would perceive Gardner's (1983) kinesthetic intelligence as meaning the coordination of the body as a whole. However, Gardner continues to discuss the use of the body in another fashion. His example includes the application of the body in more limited realms. Specifically, Gardner refers to a piano player. This use of the body may not be wholly included in kinesthetic activity and leads to a division typically noted between kinesthetic and tactile. In other words, as one sees tactile as using a paintbrush, playing the guitar, or moving manipulatives around a tabletop, kinesthetic is considered jumping over hurdles, swimming, and performing strikes against an opponent in karate.

Gardner (1993) continued with a blending of tactile and kinesthetic intelligence. Whereas the movement of the entire body may be considered kinesthetic and the use of the hands tactile, Gardner described the use of the motor cortex and the utilization of the left and right brain hemispheres. Furthermore, he comments upon the existence of apraxia as justification of bodily-kinesthetic intelligence. Humans, as well as other species, must exhibit some mastery of their bodies to survive. Gardner adds the use of other intelligences in concert with bodily-kinesthetic intelligence. The use and analysis of multiple intelligences is not a stand-alone concept. For example, a performing musician is using linguistic intelligence, musical intelligence, and interpersonal

intelligence. If the musician starts dancing on a stage one must add spatial intelligence and bodily-kinesthetic intelligence. One of the ways Gardner further clarifies the use of multiple intelligences is by commenting spatial intelligence can be used by a sculptor, a sailor or others. Gardner adds that growing children are continually faced with activities enabling them to continue to gain control over their growing bodies, despite focusing on reading, writing, and arithmetic. The intelligences exist in all humans and may be exhibited at any point in time. Differentiation between kinesthetic and tactile is not established with Gardner (1983, 1993).

A study by Sener and Cokcaliskan (2018) proposed to establish not only a preference of learning styles among students, but among intelligences as well. The study involved 88 students taking part in structured interviews to determine learning styles and prevalence of intelligences as well as a breakdown of the results by gender with 45 females present and 43 males. Additionally, the study involved middle school students from 5th grade through 8th grade. The students were Turkish and learning English. Sener and Cokcaliskan (2018) found the preferred learning styles, out of visual, auditory, kinesthetic, tactile, group, and individual, to be tactile and auditory. The study also concluded, out of Gardner's (1983) multiple intelligences, the most dominant were naturalistic, visual, and kinesthetic. The other intelligences include verbal-linguistic, logical-mathematical, musical, interpersonal, and intrapersonal (Gardner, 1983). The study noted there was no significant difference between genders and the preferences stated. Two significant positions regarding the results remain the age of the participants and the number in the study. The number of participants is duly noted by the authors along with their recommendation to repeat the study with a greater number of students.

The age of the students and lack of distinction between learning styles is noteworthy. To further comment upon Gardner's description of bodily-kinesthetic intelligence, Sener and Cokcaliskan (2018) found both tactile (within the learning style) and kinesthetic (from multiple intelligences) as a priority. This finding aligns with Gardner's (1983) ideas of growing youth and is not surprising.

A study by Ramerzani, Dehgahi, and Hashemi (2015) involving 40 English language learners found somewhat contrary results. The study included high school students of which 20 were female and 20 were male. And, through a series of structured in-depth interviews females preferred an auditory learning style, whereas males preferred learning kinesthetically. Comparatively, females least favorite method of learning was kinesthetic and for the males the least favorite was tactile. Note the term kinesthetic learning implies the use or movement of the whole body whereas tactile implies the use of the hands. Some of the comments upon the results by the authors include reference to the Iranian culture of the participants. This included the fact that women may be more likely to simply listen (auditory), whereas the males preferred threatening and intrepid activities. No comment was made regarding the variances or similarities between kinesthetic and tactile learning. This study was not based upon nor did the study include Gardner's (1983) multiple intelligences.

Whether Gardner's (1983) theory of multiple intelligences is included and the bodily-kinesthetic intelligence is considered paramount, six learning styles (visual, auditory, kinesthetic, tactile, group, individual) are considered a source, or the three basic learning styles (visual, auditory, or kinesthetic), this study exactly includes manual manipulation. Arguments may have been brought forth to direct such clarification, but

the use of kinesthetic in the study fall in line with the absorption of Gardner's kinesthetic concepts and the traditional three learning styles. The distinction between tactile and kinesthetic remains insignificant.

This study is designed to test the use of clay and its kinesthetic manipulation to communicate definitions of technical nomenclature. Some research indicates the learning of science or specialized terms is unlike the assimilation of other words in language (Young, 2005). While it is agreed that specialized language should be addressed separately (Dale, 1947; Seddigh & Shokrpur, 2012; Young, 2005) there also remains the emphasis upon delineation between such technical terms and common words (Dale, 1947). The use of clay served to ensure distinctions between scientific words. In other words, the English language has many terms with multiple definitions. As an example, the biology term cell could refer to any number of things like a location in a beehive, an address on a spreadsheet, a place where a prisoner resides, or a basic unit of life. By using clay, one would ensure the correct definition was being used. With biology terms the initial error of a high school science student making a nucleus with neutrons and protons was easily seen as the clay creation was visible to the educator. The educator was then able to steer the student to make a cell nucleus with its various components. Modeling clay has proven useful within limited fields. At the elementary school level, younger children (Chumark & Puncrebutr, 2016; House, 2007) used clay to create and learn. While the application is not at the level of biology students and the rigor of learning vocabulary, the article does substantiate the pedagogical approach of using clay. Kooloos et al. (2014) completed a study in which an anatomy class a comparison was done for retention of a medical procedure. The study involved three groups of anatomy

students. The first group actually witnessed a medical procedure. The second group used clay to recreate the procedure. The third group viewed a film of the procedure. The conclusion was that the clay was not as effective for recall and anatomical knowledge as the actual experience; however, the clay group had higher assessment results than the final group which watched a film (Kooloos et al., 2014). The results bode well for the use of clay. And by using clay the students were intimately engaged in the lesson and the medical procedure. The succession of all three groups aligns with Dale's cone of experience as the actual real-world procedure, or purposeful experience, would communicate to the students the best with the clay creations being a contrived experience and the film having sights and sounds further removed from the actual procedure as an observation (1947). House (2007) used clay to develop and understand the meaning of art and clay terms directly which proved successful. The application here was the use of clay, but more importantly, the actual understanding of the terms within the arena of art and working with clay itself.

Applying Words in Sentences

Consistency within the control group in this study, as with any study, was imperative. The analysis of the data included not only a comparison of the results from both Group S and Group C but also an assessment of the success of the pedagogical methods used. The focus of the study was to compare the use of clay versus a more traditional method of vocabulary acquisition. Thus, the control activities could not have featured kinesthetic or tactile pedagogy. Additionally, the method chosen had to be consistent and one not requiring a great deal of instruction. Hubbard (1996) states one "reads the definition and uses it in sentences until one has a clear concept" (p. 27).

Although Hubbard does not clarify whether one writes them out or mentally forms them, for the study at least three sentences per word will be documented in writing. Sentence writing is considered more of a symbolic activity on Dale's (1947) cone of experience. This viewpoint suggests writing sentences is a less effective, instructional method than a more engaging, hands-on contrived experience like using clay. Therefore, all control groups in this study utilized sentence writing as the control method in response to the first research question concerning the effectiveness of clay.

Students within the control groups wrote sentences demonstrating an understanding of the vocabulary words in each unit. Other methods of instruction were promoted to the participating students to employ. The variety of options included memorization exercises, reworking definitions, writing stories or essays, and the use of glossaries, texts, or dictionaries. However, the students ended up only writing sentences.

The sentence writing entailed the creation of three sentences wherein the meaning of the word was demonstrated for the participating teacher. Hubbard (1996) calls for students to use the meaning the word appropriate to the subject at hand. Following up on a previous example, a student could have written, "Some organisms have one cell while others are multicellular." The student could have written, "The cell was dark and the inmate afraid after the lights were turned off." The later example includes the use of an inappropriate definition. Furthermore, a sentence such as, "I like to study about cells," does not convey an understanding of the word cell. It is a complete thought; it is a proper sentence, but, it does not indicate in any manner to the teacher an understanding of the word. In actuality, the word cells could be replaced with a word representing any other topic and still be a logical sentence. Hubbard points out that the creation of sentences

leads to gaining understanding of the word. The proper use of words is in sentences, thus there is a wholeness about writing sentences with the nomenclature from the study.

Summary

With such a small growth in vocabulary scores (U.S. Department of Education, 2013) and illiteracy remaining such a concern, there needs to be a sound method of vocabulary pedagogy. Even with the reported increase in SAT scores and the four given reasons by Speyer (2004), no sound instructional methodology was discovered or created. Amidst the lack of growth in public schools and desire for increasing SAT scores educational organizations should be able to purport a sound pedagogy for vocabulary acquisition.

The evolution and differentiation of learning styles could provide some answers. Pritchard (2014) promotes the use of learning styles but does not recommend either informing students of their style or forwarding one over another. Instead he recommends using them all in hopes of strengthening weaker styles. Likewise, Gardner (1983) with his theory of multiple intelligences, states that all the intelligences are present and often work in tandem. Other authors such as Rice (2013) continue to recommend the specific application of the learning style individual students tested into or prefer. Rice recommends educators use pre-assessments and then plan accordingly. Rice recommends inclusion of the learning styles in lessons, not as an ultimatum, but as a point of focus or more weight. In other words, if the class, and the individuals within the class, have tested to be visual, then use visual activities in the design of the lessons.

Pritchard (2014) argues for the use of all types of learning styles being applied in the classroom versus Rice (2013) who calls for a tailoring of lessons to the student and

his or her stated needs. While it seems obvious and effective to play on the student's strengths, a look at the workplace and the world may dissuade such application of the learning styles. Employers and organizations may not apply or develop training for the workplace based upon learning styles. Furthermore, mastering one's home, finances, purchases, maintenance of possessions, and relationships is not designed around any particular learning style. Life does not imitate the classroom. Reflection upon Dale (1947) may in fact lead one to state the exact opposite. The classroom and experiences outside the class dictate the creation of lessons and the efforts in imitate life itself within the scope of the class.

The use of dual-coding theory in conjunction with Dale's cone of experience provides a strong connection. Dale (1947) maintains the more faculties employed the better the learning will be and the more the student will recall from the lesson. DCT maintains that when the verbal learning is combined with visual activities will result in greater learning (Kortz et al., 2017, Moody et al., 2018).

Too often, the actual classroom methodologies employed are chosen with little reasoning. The Georgia Department of Education (2015) provides a toolbox with a variety of vocabulary teaching ideas. There is no guidance, no recommendations as to which method to use when or with whom. Recommendations from researchers include having students read (Nation, 2015). Blachowicz and Fisher (2002) recommend reading. Blachowicz and Fisher also promote more engaging or interactive activities to learn vocabulary along with others including Marzano (2010).

While learning styles present potential for lesson creation, and multiple intelligences provide further insight regarding approaches to individual students there

remains a lack of certainty for lesson composition. Additionally, the shotgun approaches forwarded by authors concerning the actual classroom activities increases the uncertainty for the creation of lessons.

A review of Dale (1947) and his educational theories concerning the cone of experience led to the creation of a study employing what Dale refers to as a contrived experience using modeling clay and a more symbolic educational method of writing sentences. Both the use of clay and writing of sentences follow the ideas of Hubbard (1996) put into practical use in the classroom.

The review of the literature exhibits a lack of discernment of the best vocabulary pedagogy. Additionally, the lack of indecision concerning learning styles, even so far as the distinctions between kinesthetic and tactile learning, enhanced the findings of the study and helped to clarify the goals of the study and allowed a sound resolution of the findings.

Chapter III

METHODOLOGY

This chapter explains and justifies the methodology used during the execution of the study. The chapter contains a reiteration of the research questions and explanations on how the instruments used to capture data were created. The population, sampling methods, and procedures are discussed within the chapter. Mixed method research designs, such as the explanatory sequential design used in this study, justify quantitative findings with data obtained from the qualitative aspects and even create new angles to view data (Creswell & Plano Clark, 2011). Anticipated methods for both quantitative and qualitative data analysis will be presented along with a breakdown of variables for control and treatment groups.

The study, modeled after Creswell's (2014) explanatory sequential design, consisted of a quantitative data strand preceding a qualitative data strand. Within the study there was also repetition to aid in bolstering the results. Once a group of twenty vocabulary words were completed, another set of different twenty vocabulary words were then addressed in the same manner. Students took pretests, then Group Clay (Group C) and Group Sentence (Group S) participated in the study procedures. After they were complete, there were posttests and retention tests issued. Upon completion of the testing, student participants completed surveys. The participating teachers were interviewed at the end of each unit. The purpose of including the qualitative data strand

was to supplement and potentially validate the findings from the quantitative data (Creswell & Plano Clark, 2011).

All instruments, tests, survey questions, and interview questions were driven by the following research questions:

1. Is there a difference in vocabulary test scores between students who study biology vocabulary using modeling clay and those who do not use clay?
2. What are students' and teachers' perceptions regarding the use of modeling clay for biology vocabulary acquisition?
3. What are the challenges and benefits of using modeling clay for biology vocabulary acquisition in the classroom?

Responses to the first research question comprised the quantitative data strand. The pretest, posttest, and retention test results were used to verify and negate the first research question. The second research question was answered with data from the surveys which were administered to participating students. While the survey questions required opinions, the responses were converted to numerical values and thus the surveys for this study were quantitative. The format of the surveys was a Likert scale used by students in response to the questions on the survey. The second research question was also answered, as well as the third research question, by interviews with the teacher participants after each vocabulary unit. The interview was conducted with the teachers on a one-on-one basis.

The purpose of the study was to discover potential benefits of using physical manipulation with clay in learning biology terminology in Group C. The control group, Group S, had limited freedom in the methods used, however, no kinesthetic instruction

was allowed in Group S. The classroom set up with clay for Group C was different from that of Group S. Teacher participants were provided with hypoallergenic clay, tools, labeling paper, rolling pins, and cleaning wipes as well as instructions, checklists, and pretests prior to the commencement of the study. In all classes, Group C and Group S took place at the same time in the same room. The items provided and tasks to be accomplished were different.

Students, per IRB, were required to have parental permission prior to the commencement of the study (see Appendix C). Likewise, the teachers were required to provide consent to execute the study per IRB (See Appendix D). The students in Group C were provided with an example of a non-biological term to understand how the study was conducted. In Figure 1, the example was a pen. With this example, the students could plainly see what was expected. The example includes various parts of the object distinguished by color. Each class was provided with two different colors of clay, although not necessary it helped to provide some clarity. Additionally, the students could see the labels for the different portions made from pieces of a file folder. And finally, there was an overall label provided which named the clay representation of the term.

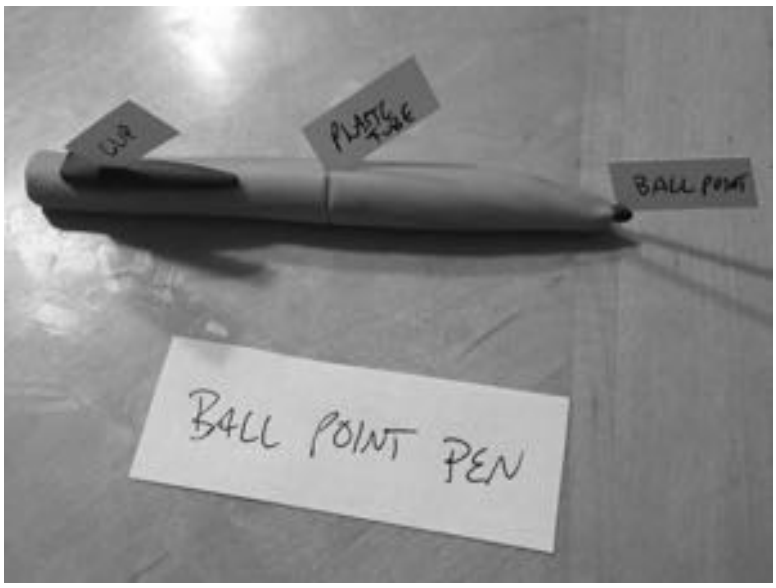

Figure 1. A non-scientific example of using clay to create a definition.

In Figure 1, there is a clip, a plastic tube, and a ball point. Each of these parts was labeled. The overall label would be placed upside down on the table (or desk) and the teacher would come by and say "pen" or "ball point pen" and flip the label over. If the label matched what the teacher said the student would then move on to the next word. If clay creation was not accurate, then the student would make changes or improvements in the clay (Hubbard, 1995). This was repeated for all twenty words in each unit. The teacher was the judge for all the student clay work.

An example of a biological term is provided in Figure 2. In this example, a eukaryotic cell was provided. This was given to both teachers as a model for judging purposes. Examples of student work can be seen in subsequent figures in Appendix E.

Figure 2. Example of biology cell unit term in clay for teacher use.

While the example shown was a term from the cells unit of Group C, the same directions and execution procedures applied to the genetics unit. The same pretest, posttest, retention test, survey, and interview line-up was employed. As students worked on genetics terms in Group C, there were also the same genetics terms used in the study for Group S. The 20 words from each unit can be seen in Appendix A and Appendix B. The list of terms formed the basis for the assessments in each unit. The tests used as pretests, posttests, and retention tests were identical. The cells unit test can be viewed in Appendix F and the genetics test may be viewed under Appendix G.

Having the interviews conducted after the tests and surveys, the study framework provided a sound representation of an explanatory sequential mixed methods design (Creswell, 2014). The only variant being the repetition of the unit cycle as the design

was conducted with the cells vocabulary words and then repeated with the genetics vocabulary words.

Population and Sample

The participants for the study were attendees from public high schools in Southwestern Georgia, a rural and lower socio-economic status area. Schools were contacted from within the local RESA (Regional Education Service Agencies). The objective was to have a number of schools with biology instructors teaching at least two classes of biology. With two classes, one would have served as a Group S and the other would serve as a Group C. Due to the limited responses of schools, only two biology teachers were willing and participated in the study. The total number of classes was five with one teacher having two biology classes and the second teacher instructing three biology classes. The instructors were seasoned educators who had taught biology for at least three years. The nature of the treatment (i.e. using modeling clay) required an instructor with strong classroom management skills and a good ability to keep students on task. Teacher participants were asked to fill out a brief, anonymous demographic survey to obtain data regarding their gender, race, years teaching, years teaching science at the high school level, and their level of education.

The student participants were high school freshmen. The class sizes varied from 12 to 24 students. There were no criteria regarding gender, race, or ability for selection. Students only noted their race and gender on assessments and surveys. Any other data regarding students was not called for and deleted or kept anonymous if added by the student.

Student participants took place in the study as a member of Group C or Group S and then switched groups. The population of the participating students was 95, resulting in a complete database of 190 individual data points less attrition for some assessments and surveys. Due to equal options for student participation concerns from IRB Group C took place in the same classroom as Group S. The same teacher monitored both groups. One biology instructor oversaw the study of two classrooms in the spring of 2018 and a second teacher oversaw the study of three classrooms in the fall of 2018. Both schools participating in the study maintained a block schedule, hence the biology courses were completed in one semester. During this study, there were no co-teachers or para-pros involved and all interviews were conducted with the two participating teachers.

Training of the instructors took place individually. One teacher was met off campus and the other within her classroom. The training included an overview of the program, incorporation of the treatment into the curriculum, procedures for treatment in the classroom, testing, checklists, anonymity, resolution of concerns, surveying, and qualitative interview procedures. Teachers involved with the study were given examples and photographs of clay representations and lists of the vocabulary terms to provide a better understanding of Group C and what their students were expected to do. Teachers, when overseeing Group S were directed to employ only reading and memorization of definitions, writing of sentences, and similar activities that do not contain manipulatives.

The study required the active participation of approximately 100 high school students and 2 biology teachers. The execution and interaction protocols were submitted to the Valdosta State University Institutional Review Board (IRB) for approval (See Appendix H). The IRB submission included the forms requesting individual consent

from students, teachers, and administrators, as well as parental/guardian consent forms for all students in the control and treatment groups.

Participation was voluntary for all, and no student was forced to participate in the study. To help prevent attrition and refusal to participate, all procedures and requirements were explained in detail to teachers, students, and parents/guardians. No school names, teacher names, or locations, other than to state "Southwest Georgia" were noted to maintain confidentiality.

Setting

The study setting was the high school classroom. The schools involved in the study used nearly identical room arrangements. The study which took place at the beginning of 2018 had a long counter at the front of the room where the clay was kept in plastic tubs. The study occurring in the fall of 2018 had a table with clay and other needed supplies. The classrooms also had individual desks where the students sat for regular instruction as well as the study activities. Students writing sentences were also seated at their desks. Any additional materials needed were stored in the room and obtained when appropriate. Additional items included strips of paper and office folder for labeling, scissors, rolling pins, bleach wipes for cleaning, pens, and paper. The clay and related items were put away when not in use.

While students worked the teachers circulated to check work done by students. When the Group C activities involving clay were not taking place students were also taking the tests and surveys at their desks. Students were able to access their textbooks as needed regardless of their assignment to Group C or Group S.

Teachers from participating schools completed the paperwork for the students/parents before the study commenced. Students began with the pretests from Group C and Group S at the start of the cells and genetics units. The teachers were responsible for tracking student progress. When all of the students in the classes were complete, the posttests were administered whole group and collected. During the week after posttest completion, the retention test and surveys were administered and filed. Upon notification of the completion of the paperwork, the tests and surveys were collected. Once the tests were removed from the campus they were graded by hand. Surveys were also tallied by hand. All data was entered into spreadsheets and then referenced for further statistical analysis.

Finally, both schools involved in the study were on a block schedule which assisted in the timing of the study. Block schedules contain four longer class periods. Traditional scheduling contains more classes meeting for a shorter period of time. With the block schedules the class periods are approximately one and a half hours in length. The longer timeframe enabled the classes to work on the clay for a longer period at one sitting. With one school the cells unit curriculum was already completed before the study began. In the other school the cells unit of was conducted simultaneously with the classroom curriculum. For all classes, however, the genetics unit of the study was conducted prior to the classes covering the material on their respective curriculum maps. Thus, with the cells unit the students had some exposure to the vocabulary prior to the study and with the genetics unit there was no previous exposure. While this was a potential area of concern during the designing of the study, the study showed no indication of any effect on the outcome. A key point for the setting of the classroom and

planning of the lessons was that neither educator had addressed vocabulary as a separate subject before. Also, neither educator was engaged in any type of program such as blended learning, on-line learning, or project-based education.

Instrumentation

In order to conduct the study specific instruments needed to be created. The complete assembly of created items included checklists for the cells vocabulary unit and the genetics vocabulary unit (Appendices B and C), the pretest, posttest, and retention test for the cells unit and the genetics unit (Appendices D and E), the surveys for the treatment and control groups (Appendices F and G), and the teacher interview questions (Appendix I).

Prior to the creation of any assessments was the consideration of the units to be included in the study. The Georgia Department of Education (2016) biology standards of excellence contain six standards. These standards form units such as cells, genetics, evolution, phylogeny, and ecology. The units chosen for the study needed to be within these areas and the study was designed for public high schools. The units chosen were cells, which is typically covered at the front of the course and relates to the first standard (SB1) as well as others. Additionally, the second unit chosen was genetics which relates to the second and third biology standards (SB2 and SB3). The later standards, although cycling through concepts of the first three standards, deal primarily with evolution, phylogeny, and ecology. There was no more significance placed upon the selection of the units from the Georgia DOE (2016) for the units to use. An argument may have been made for the potential ease of students in the study making cells or more basic items in

clay as opposed to creating a food web or chain or an ecological scene in clay. Such a viewpoint was not seriously considered to bear any weight in the study.

Once the biology units were determined to be included in the study the actual word lists were generated. The twenty words from each unit, totaling forty words, were compiled from years of personal experience, Georgia biology standards from Georgia Department of Education (2016), and study of Miller and Levine's (2002) biology textbook. All of the words used, except nucleus, were unique to biology and the unit studied. In other words, the word nucleus can mean a number of things, including the definitions used in physics and chemistry. But words such as hypotonic and organelle are fundamentally utilized in the study of biology. Likewise, genetics terms such as chromosome and dominant trait are not likely to be confused with other definitions. Thus, there were two considerations in selecting the list of terms: Is the term learned in the biology course and is the use of the term likely to be confused with other definitions of the word?

The creation of the tests, which were used as pretests, posttests, and retention tests for each unit was conducted once the words lists were constructed. Both assessments were composed of 15 analogies and 5 short answer (open-ended response) items. The construction of the instrument involved considerations of the type as well as the depth of knowledge (see Appendix K for the assessment on cells and Appendix L for the assessment on genetics). Brookhart and Nitko (2015) argue most tests, being multiple-choice, do not allow students to demonstrate understanding. However, most students are accustomed to the use of multiple-choice assessing and state assessments. The Georgia

Milestone or End-of-Course test, as well as nationwide test like the SAT, employ the use of multiple-choice questions. Thus, the instrument contained both multiple-choice. With research such as Brookhart and Nitko (2015) the use of other testing methods was utilized in the form of short answer questions. Short answer questions, allowing students to show their understanding in their own words, were also included as questions 16 through 20. An example of a short answer question is: Explain the function of the cell wall. Another short answer question on the cells unit assessment is: How does passive transport work?

In creating multiple-choice questions an effort was made to ensure the questions were of higher-order thinking. Having questions which challenged the students was necessary as the study design dictates the participants engaged with the same assessment three times. Higher-order thinking was required to better challenge the students by demanding that they consider the definition or concepts contained within the vocabulary words in a new light (Brookhart & Nitko, 2015). The assessments for both cells and genetics contained analogies to address the need for more challenging questions. One of the more challenging methods of assessing understanding while maintaining a multiple-choice format is the use of analogies. Analogies allow students to understand items by a new comparison and are grounded in concepts or objects they usually already know (Harrison & Coll, 2008). An example of an analogy question is: Water is to Osmosis as People is to _____ a. Trains, b. Children, c. Diffusion, d. Isotonic. The correct answer here would be answer a. Trains because water travels around and through a cell in the same manner that trains can transport people through and around the country. Another example is Bricks is to House and Macromolecules is to _____ a. Organelles, b.

Metaphase, c. DNA, d. Carbohydrates. The correct answer would be a. Organelles as macromolecules build organelles in the same manner bricks build houses.

Both the cells test and the genetics test were given to five current or previous science educators to review and critique. The members included individuals with bachelor degrees, specialist degrees, and a doctoral degree. Those participating in the assessment review had taught at either the middle school, high school, or collegiate level. One of those who reviewed the assessments was an administrator and previous science teacher. The feedback from the teachers resulted in the rewriting of one question failing to make a sound analogous comparison between the biology vocabulary term and computer technology. The overall comments proved both positive and helpful giving approval and understanding of the assessment for use in the study as outlined.

As with the assessments, surveys for the student participants needed to be created. There were no discovered surveys for the use of clay in the classroom. Similar to Group C, there were no surveys located addressing the use of sentences for Group S. Surveys were created to obtain data from Group C. Surveys were also created to capture input from Group S. Both sets of surveys were created from the perspective of answering research question two, bolstering quantitative results and, maintaining internal validity. As there were two groups working with in the classrooms with different activities taking place, there was a slight variance in the survey questions posed. Some questions on the survey were specific to Group C and the use of clay and some questions on the other survey were specific to Group S and the writing of sentences.

The primary focus of the study concerned the effectiveness regarding the use of

clay in the classroom. However, those participants in Group S were called upon to provide comparable data. In this study, Group S was given the opportunity to engage in various activities such as memorization, reading, creation of flashcards, and the use of dictionaries and glossaries. With both all classrooms the students in Group S only did the minimum, which was the writing of three sentences. This method of demonstrating understanding was based upon the research from Hubbard (1996). Thus, two surveys were created. The first for Group C with some questions regarding the messiness of clay, clean-up, manipulation, etc. The second survey for Group S with specifics about sentence writing.

The surveys were post-experimental and conducted to not only obtain information from the study, but to provide data for comparison (Fink, 1995). While the survey for Group C contained thirty questions, the Group S survey contained twenty-five questions. The majority of the Group C questions had a mirror, or similar question contained in the Group S survey. The additional five questions on the Group C survey were specific to the use and clean-up of clay and did not translate to the Group S survey.

The basis for constructing the survey items was the study research questions. The purpose of the survey was to solicit information from the student participants in a manner which was efficient yet comprehensive. The use of surveys is an effective manner to compare treatment and control groups (Fink, 1995). Thus, the design utilized was a Likert-style survey wherein agreement or disagreement was chosen by the students after the study was conducted. The survey included selections for the students ranging from 1, which denoted strong disagreement, to a 5, denoting strong agreement.

Beyond the agreement and disagreement of items pertaining to the study there were imbedded categories. Three main categories for the survey questions were used. The first type of question dealt with effectiveness (e.g., "I remembered words better after I used clay," "The clay helped me understand the words"). The second type of question pertained to perception (e.g., "I came to appreciate the clay as I did more words," "The clay was boring after a while"). The final type of question was related to challenges and benefits (e.g., "I did not like cleaning up the clay," "The clay took too much time."). A few survey items alluded to motivation (e.g., "I stayed late or after school to work with the clay").

The data from the follow-up surveys were included in the quantitative data strand due to the inevitable conversion of student responses into ordinal data. While agreeing or disagreeing exhibits opinions and is intrinsically qualitative in nature, the Likert scale responses were converted to numerical values for analysis. The data gathered has provided additional insight from a qualitative perspective and was treated as supplemental in nature to the more poignant quantitative data gathered.

The final instrument created was the list of interview questions for participating teachers. Identical to the impetus for the creation of the surveys, the second and third research questions were the foundation. The second research question specifically mentions the inclusion of teachers (What are students' and teachers' perceptions regarding the use of modeling clay for biology vocabulary acquisition?). The third research question was: What are the challenges and benefits of using modeling clay for biology vocabulary acquisition in the classroom? This last question was written with the teachers who would be overseeing the study in mind.

The questions/statements for the participating teacher interviews are contained in Appendix I. Per Maxwell (2013), the research questions should pertain to the meaning, context, and processes of the research. This foundation, coupled with the idea of focusing on "specific beliefs, actions, and events" (Maxwell, 2013, p. 78) led to the creation of interview questions pertaining to the use of clay and the creation of sentences. Additionally, the interview questions included inquiry re the planning and maintenance of the class structure and management.

The interview questions for the teachers progressed from general to specific. The later questions were written with more directed language, such as: "Tell me about the logistics of working with clay," and "How have you adjusted your lesson preparation to include the use of clay? As a student, how did you prepare to work with the clay?" In total, there were ten questions for the teachers. After the tenth question, there was always the final question calling for anything else any teacher wanted to add to the interview or clarify from the interview before closing.

Validity and Reliability

The study was executed by two female biology teachers in two schools. Despite efforts to successfully solicit half a dozen teachers and schools, the reality was having agreement from two teachers to work in five classrooms was fortunate. Both educators were pleased to participate and commented that no compensation was needed after being rewarded a token gift. This was a limiting factor which reigns in external validity and generalization of the study.

Despite having only two biology instructors, there were five classes involved in the study at two high schools. The seasoned educators had no issues with classroom

management and were able to conduct the study as designed. In both high schools, the students who took biology were freshmen, with few exceptions. Both high schools operated on a block schedule. The biology classes were also offered by an instructor who primarily taught biology.

The assessments were created for purposes of this study and peer reviewed. The peers included administration which was previously in the science classroom, and science teachers with either a master's degree or a doctoral degree. Based upon feedback from the reviews, changes were made to the assessments before implementation in the study. Assessments, one for cells and one for genetics, were used as a pretest, posttest, and a retention test. Additionally, the same assessments were used enabling sound comparisons and exhibiting consistency throughout the study.

As the tests were used three times per unit, the surveys for Group C and Group S were also repeated at the end of each unit for each class. Unlike the assessments differing for cells and genetics vocabulary units, the surveys were consistent for all of Group C and Group S. The testing of the cells and genetics units creates one line of multiple instrument usage which provides consistency and varies from the consistency in survey usage for Group C and Group S. This crossover provided a degree of validity for the study.

The interview process was also duplicated numerous times during the study. Each biology teacher was interviewed at the end of each unit. There was no variance in the interview questions posed to the teachers. Thus, each teacher was asked the same questions twice for a total of four interviews.

Lastly, the location of the study and student population was a limitation concern. The schools were both Title 1 schools in a lower socio-economic area of southwest Georgia. Even though the students were willing participants in the study, the ability to generalize the results beyond the South is limited. Consideration may be given to include other Title 1 schools with similar academic scores as biology is taught throughout the nation.

Data Collection and Procedures

The data collected to address the first two research questions was accomplished by dividing the classes into two groups by use of on-line random number generation or teacher imperative. One group was the control group and the other the treatment or experimental group. The treatment group used clay symbols and figures to create definitions for the list of vocabulary words. The control group wrote sentences (minimum of three) demonstrating meaning of the vocabulary words.

All tests were printed and answered by hand. Tests were administered by the classroom teacher and then filed for the researcher. The tests were administered whole group, thus those who finished with their sentences or clay may have experienced a wait time if others were not complete with the treatment or control group activities. In all classes, the clay element took longer to complete than the sentences. Once the tests were completed, the surveys were issued and filed similarly. At various times the researcher would visit the classrooms and collect that data. All tests were scored by the researcher and scores recorded in spreadsheets.

The explanatory sequential design for this study may prioritize quantitative data analysis (Creswell & Plano Clark, 2011). In this study, the quantitative results were

considered with a greater weight than the qualitative portions. The reasons for the stress on the quantitative portion was the use of multiple instruments as sources for data collection versus conducted interviews. The hundreds of tests and surveys provided repetition and saturation of data. The interviews took place after the units were complete and with two biology teachers overseeing five classrooms the number of interviews totaled four with eleven questions asked in each interview. The findings from the quantitative testing sources were bolstered by the surveys and the interviews.

The assessments were analyzed in various ways. The first method of test analysis was grading correct and incorrect responses to score each test. As the instrument contained both multiple-choice responses and short answer all the tests were graded by hand. Scores were compared between Group C and Group S classes, and broken down by gender. For example, the average scores will be computed for all Group C students, for all Group S students, for all males, and for all females. Standard deviation was calculated for all groups as well.

Beyond the obligatory comparisons of means and standard deviations, the analysis of the assessments included *t* tests for insight as to the efficiency of the program. These tests also provided a look at the validity of the null hypothesis that there was no significant difference between using clay in biology vocabulary acquisition and other, non-manipulative means. The fact that the assessment is the same in each case allowed more accurate comparisons between analysis segments. Using the same test naturally led to increasing scores due to repetition, but students were unable to see their prior tests due to the study protocol and the fact no names were included on the assessments.

These analytic procedures will occur with every administration of the tests, meaning that there were three rounds each for the cells unit test and the genetics unit test (pretest, posttest, and retention test) for the five control classrooms as well as the five treatment classrooms. In total, there were 514 tests delivered, graded, and included in the analysis.

Once all testing was completed for a unit, cursory analysis was done in a longitudinal manner, comparing each set of assessments using mean scores and standard deviation. All results have been displayed to demonstrate the effectiveness of the treatment in order to test the null hypothesis. Commentaries on results prior to the inclusion of survey data has been included.

Students in the study took a total of nearly 180 surveys upon the completion of the cells unit and the genetics unit. The Likert-style scale survey included 30 questions for Group C and 25 questions for Group S. The questions all had five categories from strongly agree to strongly disagree. All 25 questions within the Group S survey directly match questions in the Group C survey. This allowed for a direct comparison of responses between the classes. Ordinal number conversion and subsequent mean data analysis was conducted. Commentary upon high or low means were provided. Although most items on the survey were qualitative in nature, statistical analysis dictated the surveys be included in the quantitative strand. Regardless of the strand, the results were recorded and the information obtained allowed further commentary upon the quantitative and qualitative results obtained strengthening the value of the study.

There were four interviews conducted for this study. The same ten questions were asked during each interview. Additionally, at the end of each interview the

participating teachers were asked if there was anything else she wanted to say. The recordings and notes from the interviews were culled through for the study. Analysis of the comments and answers was conducted with the use of a matrix which included individual words, synonyms, and phrases. The searching for themes was conducted within the four interviews. Any recurring and overlapping themes or ideas were noted. The feedback and any implications for the study were summarized and included in the final analysis. The primary purpose of the qualitative strand within this study was to provide supplemental bolstering or refutation and experimental application of the clay pedagogical procedures.

The cells unit was completed prior to the genetics unit in all classes in all locations. All assessments and survey completion was conducted at the students' desks. Upon the completion of each set of tests the teacher provided notification and the assessments were collected in person. The assessments were not graded by the teachers nor were they graded on site. Additionally, as one class was completed so were the other classes.

The demographic information on the tests and surveys was limited to gender and race only. For the sake of anonymity there were no names asked for or noted. Any names written in error were struck through. The options for race included White, Black, Hispanic, Asian, and mixed. Each group of tests were scored and recorded in spreadsheet format and then analyzed with measures of central tendency including mean and standard deviation. Scores were then statistically analyzed for significant differences.

Although student assessments and surveys had gender and race noted upon them, there were no files created and the only grouping of records done was merely by the class

they attended. The teachers were simply noted as being Teacher A, from the first school approved in the Spring of 2018 and Teacher B from the second school in the Fall of 2018. No other system was used to denote or classify students. Data was summed as aggregate to avoid any loss of anonymity.

Upon completion of the Group C clay activities, which always took more time than Group S sentence activities, the posttest was administered to all students. Whether the students were in Group C or Group S they all took the posttest at the same time. The timing of the posttest after all were completed did lead to delays, in every case, for those in Group S. In the week following the completion of the posttest the retention test and survey were administered at the same time to all participants. This was the same with all students in both high schools in all classes.

The researcher dropped off and picked up all tests and surveys. If not enough copies were provided teachers made copies as needed. All assessments and surveys were done in writing by the students. Tests and surveys were graded and compiled by the researcher. Teachers did not grade any assessments or items. The units took varying amounts of time, from two weeks to a month, to complete.

The physical data collection occurred in all participating school locations numerous times. Once approval was obtained by the superintendent for each school, contact was made with the principals, and finally the teachers. Arrangements were made to visit and deliver materials. All items, checklists (Appendices A and B), assessments (Appendices C and D), and surveys (Appendices F and G) were delivered and collected in person. No instruments were graded on site. Participating educators contacted the

researcher at various times regarding progress, completion, and the like by email, phone, or text.

Teacher interviews were conducted when retention tests were gathered. The interviews were one on one with the researcher. The interviews were conducted both on and off campus and were facilitated by the use of note-taking and audio recording.

Limitations

The study entailed a live classroom study where students and teachers took part in unfamiliar pedagogical practices. Thus, there were a number of activities and events which are hereby considered as limitations. The limitations include such factors as time and construction.

Time was a limitation for several reasons. To begin with, all Georgia public schools have biology courses that cover the same science standards and are assessed ultimately by the same mandated tests, but the timing of each unit and the schedule of the school are not fixed. Thus, the various units started at different times and took different lengths of time to complete. Every effort was made to have the studies continue at a consistent pace. Both teachers were able to complete the study by the end of the semester, which was also the end of the course. In the Spring of 2018 semester the final interview was very near the end of the course itself. There were several in-person exchanges of materials and meetings during the first study which led to fewer planned, but more organized and productive meetings with the second study.

Secondly, while the first unit of the study occurred without any pretense as to timing, the second unit covering genetics happened faster in both schools. The reason is

both teachers learned that it was easier to set up and have a longer period of time dedicated to the creation of clay models than set up and breakdown day after day. Additionally, comments pertaining to the study indicated that the use of clay in longer periods of time enabled the physical manipulation of the clay to happen more easily due to the clay being softer from use.

As regards the construction of the study itself, the use of twenty words in cells and twenty genetics terms may possibly be a concern. If the study had used fifty words or only ten the results may have varied. The decision to use twenty words per unit was a point of compromise.

Data Analysis

The first research question was: Is there a difference in vocabulary test scores between students who study biology vocabulary using modeling clay and those who do not use clay? This was answered by using several methods of statistical analysis. Measures of central tendency were first used to acquire the mean and the standard deviation. Comparisons of the mean scores, as improvements or losses, from the initial pretest was vital for the study. This indicated whether or not the treatments in Group S or Group C were worthy in its most fundamental analysis. Additionally, *t* tests were used to determine statistical significance with regard to the research questions or the null hypothesis of the effectiveness of the instructional methodology employed in the classroom. SPSS was used to create and verify statistical analysis of the data for the study.

Statistical comparisons were completed with regard to the pretests and posttests as well as pretests to retention tests. This included aggregate comparisons of Group S and

Group C scores and gender scores. The *t* tests were similarly conducted as aggregates to note improvements from pretest scores and in comparing Group S and Group C.

The second and third research questions were answered through quantitative and qualitative means. The second research question was: What are students' and teachers' perceptions regarding the use of modeling clay for biology vocabulary acquisition? The third research question was: What are the challenges and benefits of using modeling clay for biology vocabulary acquisition in the classroom? The quantitative method used was a survey. The survey was taken by the students and mean scores were calculated. With the mirror questions, further analysis was conducted by the use of *t* tests.

The qualitative methodology used for the second and third research questions was a series of interviews. The interviews were conducted one-on-one with Teacher A and Teacher B. Upon completion of all interviews analysis of notes and recordings was conducted per Tesch's 8-step process (Creswell, 2014). With common themes noted the answers to the questions were answered within the context of the responses given. The explanatory sequential mixed methods design (Creswell, 2014) was strategically implemented twice. The assessments were used within two units. The surveys were all conducted twice at the close of each study unit. The interviews were also conducted twice at the end of each study unit. The repetition of the results within the study may not lend credence to the accuracy of the results, but they do bolster the precision of the instruments and the study results.

Summary

The study was conducted per Creswell's (2014) design, under the direction and approval of Valdosta State University's IRB (See Appendix H for the Institutional

Review Board Approval), with the further approval of the administration from two Georgia county superintendents, and the volunteering of two veteran educators and 96 students.

The explanatory sequential mixed methods design was conducted in 2018 in both eh Spring of 2018 semester and the Fall of 2018 semester. The study involved the creation of all instruments (See Appendices D, E, F, and G) and their analysis. Analysis of the tests included calculations of *t* tests, *p* values, standard deviation, and mean scores. The analysis of the Likert-style surveys included mean analysis. The tests analysis was conducted as an aggregate and also broken down by gender. These items, totaling over 700, provided the quantitative data strand.

The quantitative data strand was bolstered by the use of teacher interviews where common threads were discovered and noted for inclusion in analysis and summary. The interview instrument is located under Appendix I. Although the interviews were four in number, they provided insight regarding classroom management, classroom planning, and provided a foundation for future research and kinesthetic execution in the classroom.

Chapter IV

RESULTS

This study was designed to capture data pertaining to vocabulary pedagogy from the high school classroom. The study was conducted during both the spring and fall semesters of 2018 at two separate high schools. Data collection for the study included assessments, surveys, and interviews. Assessments pertained to either the high school biology cells unit or the unit on genetics and were given as pretests, posttests, and retention tests. Surveys were provided for those using clay and those writing sentences and given after the unit on cells and after genetics. The interviews were conducted with each teacher after the cells and genetics units. The assessments on cells and genetics were used three times each as pretests, posttests, and retention tests. These tests and their subsequent analysis formed the major component of the quantitative data strand. With these tests, statistical analysis was conducted by comparisons of pretests to pretests, posttests to posttests, and retention tests to retention tests of the treatment and control groups. Additionally, a similar analysis was conducted with respect to gender.

Likert-style surveys, completed by the students, were also analyzed for outliers and commonality between pedagogical methodologies. The surveys were analyzed as an aggregate containing all the responses. The surveys were supplemental to the assessments in completing the quantitative data instruments for the study. Although

surveys, in some situations, may be considered qualitative, the numeration of the results placed their analysis in the quantitative realm. Both surveys used did solicit opinions but only on an agreement-disagreement scale. Therefore, the survey analysis was quantitative. The surveys provided complementary data for both the qualitative and quantitative strands. The only pure qualitative analysis was obtained from teacher interviews.

Group C participants made use of clay as a medium to produce physical and visual images of biology terms. While the actual models were not graded but simply done to communicate an understanding of the word or terms, photographs were included to better illustrate the study procedure. Figure 3 shows a student workspace, a vocabulary checklist, clay, and a rolling pin (made from PVC pipe). Note the student workspace is located at his desk. In all classrooms, the teachers chose to have students work at their own desks with the clay instead of having them move to work with the clay. In both classes there remained a central location for all clay and supplemental supplies. There was no need to make any alterations in class setup for Group S.

Figure 3. Student workspace with checklist, clay, rolling pin, and pen.

The following example of student work, Figure 4, is similar to Figure 3 with the addition of labels being worked on for various clay components. This example also includes a checklist, textbook, rolling pin, and clay. As with Figure 3, this is from the cells unit vocabulary list.

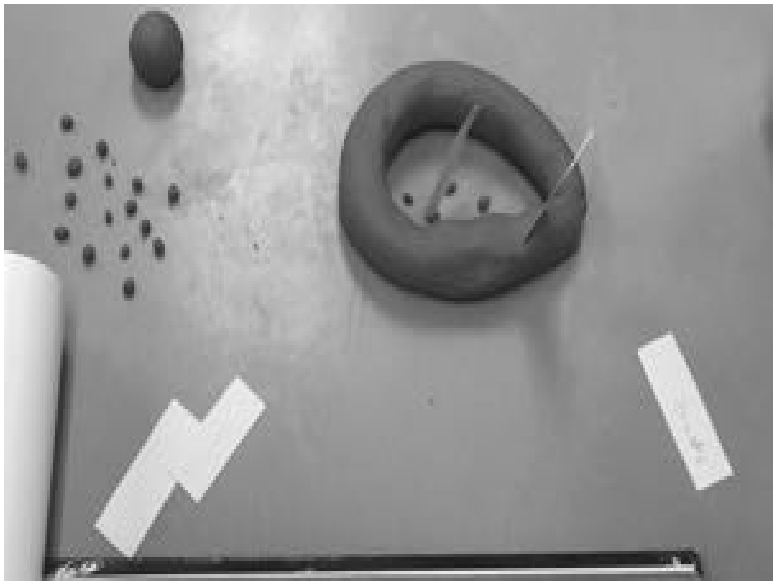

Figure 4. Student work showing labels in the clay creation.

Another image, Figure 5, shows student work from the genetics vocabulary list. In this instance, the clay representation being created is a Punnett Square. In addition to the work being created at a student desk, this work was created on a file folder for the sake of cleanliness. A more comprehensive collection of images from Group C may be viewed under Appendix E.

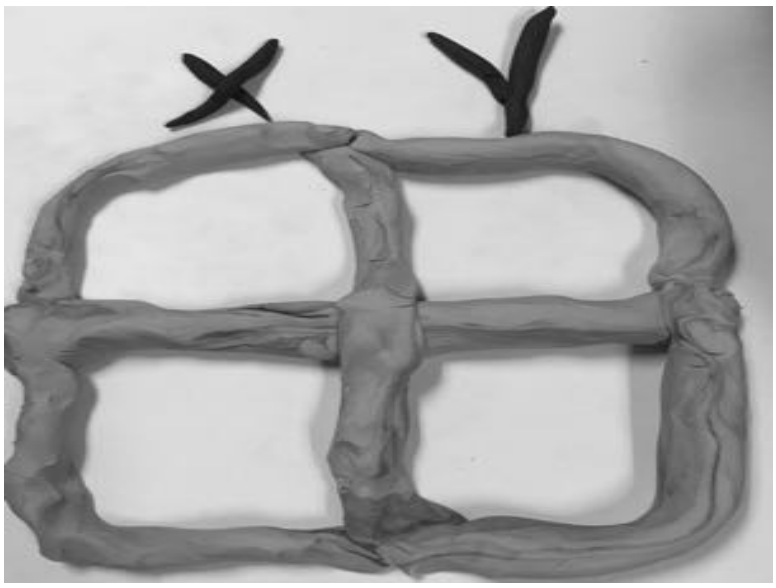

Figure 5. Student work from the genetics unit.

The schools used were public high schools in Southwestern Georgia. The first school used in the study (Spring of 2018) contained grades 9-12 with a population of 1,030 students. The second school in the study (Fall of 2018) contained grades 10-12 with a population of 1,001 students. The first school had a population comprised of 91% Blacks and Whites. With a Black population of 54%, the second highest population was White at 37%. The 9% remaining was 4.5% Hispanic, 2.5% Asian, and 2% mixed. The second school possessed an overwhelming percent of Black students at 78%. Only 14% of the population was White. The remaining demographic was composed of 7% Hispanic and 1% mixed. In both schools mixed is defined as a combination of two or more races. The races considered within these schools are Blacks, Whites, Hispanics, and Asians. Both schools had a virtually even distribution of males and females with a 50:50 ratio in the first school and a 49:51 in the second school.

The complete data set for the study involves an aggregate of 89 males and 92 females. 63% of the student participants were Black, 32% were White, 3% were Mixed, and 2% were Asian.

The study involved the participation of five separate classes. The high school conducting the study in the Spring of 2018 had a biology instructor who oversaw the study in two classes. The second school (Fall of 2018) had one teacher over three classrooms. For this particular semester, biology was the only course she taught, graciously allowing the study to occur in all her classes. The information regarding the teacher demographics was obtained using a survey completed by the teachers prior to the start of the study (see Appendix J). The first participating teacher was a white female with a BS in Biology and a Masters of Teaching degree. She had three years of experience teaching science and biology. The second teacher participant was an Asian female with fifteen years of experience teaching science and ten years of experience teaching biology. She possessed a BS in Education and a Masters of Science degree.

Research Questions

The study was designed bearing the following research questions in mind. The answers to the questions contained both quantitative and qualitative information.

1. Is there a difference in vocabulary test scores between students who study biology vocabulary using modeling clay and those who do not use clay?
2. What are students' and teachers' perceptions regarding the use of modeling clay for biology vocabulary acquisition?
3. What are the challenges and benefits of using modeling clay for biology vocabulary acquisition in the classroom?

The first research question, being quantitative in nature, was answered through the use of assessments. Surveys and interview analysis were used to answer the second and third research question. The questions proposed were best answered by the use of a mixed methods design with the quantitative data being gathered before the qualitative data. More specifically, the order of instrument dissemination and utilization for the explanatory sequential mixed methods design was pretests, posttests, and retention tests, followed by surveys for both the cells unit and the genetics unit. Finally, teacher interviews were conducted for each biology unit.

Being mixed methods, the resultant data was comprised of both a quantitative data strand and a qualitative data strand. Having the quantitative strand first in execution and the qualitative second comprises the sequential explanatory mixed method design. The qualitative data has been analyzed to reveal the existence of any potential bolstering of the test scores by the surveys or interviews (Creswell & Clark, 2011).

Quantitative Data Analysis

Per the design of the study, the intention of the quantitative analysis was to answer the first research question: Is there a difference in vocabulary test scores between students who study biology vocabulary using modeling clay and those who do not use clay?

The tests for the study were comprised of both analogy style questions and short answers. The analogies constituted 15 of 20 test items and the short answer questions comprised the balance of the 20 total test items. Both tests were identical in structure. Additionally, both assessments were used within each unit (cells and genetics) as the

pretest, posttest, and retention test. The cells test is located under Appendix K and the genetics test is included as Appendix L.

The following table, Table 1, contains an aggregate comparison between pretests and the subsequent posttests and retention tests. The presentation order is Group C followed by Group S. While the change in scores from a lower level to a higher level is discussed and the implications noted, the first comment made concerns the level of the score. For both groups, the level of performance is rather low. Both Group C and Group S participants had pretest scores below that of a 30%, meaning, on average, the students got more than 7 out of 10 incorrect. A cursory glance at the posttest and retention test scores also reflect a rather low performance. Without much commentary on the population, location, demographics, and success of populations in lower Georgia compared to the rest of the South or the nation as a whole, the students who were present were very involved and had positive attitudes and were gracious and cooperative.

Table 1

Assessment Results from Cells and Genetics Units by Pretest, Posttest, and Retention Test

Group	Test	Cells Unit			Genetics Unit		
		n	M	SD	n	M	SD
Group C	Pretest	46	27.02	12.92	49	27.04	15.58
	Posttest	40	36.38	15.65	44	50.68	18.32
	Retention test	41	42.56	17.25	41	47.56	19.75
Group S	Pretest	43	28.21	11.36	43	30.81	17.79
	Posttest	40	44.63	16.69	41	50.49	16.27
	Retention test	45	46.56	16.30	41	41.71	19.58

Table 1 displays the results of the assessments per unit. This data demonstrates a similar increase in scores from the pretest as well as building the internal validity of the study. For example, the increase in the cells unit for Group C was from 27.02 to 36.38

which was a gain of 9.36 from pretest to posttest. The gain to the retention test went up to 15.54. The genetics unit also showed an increase, but the retention test score fell off from the posttest score. Specifically, the posttest showed an increase of 23.64 points and the retention test showed an increase of 20.52 from the pretest. Congruently, in Group S the cells unit had a higher posttest test score in the cells unit and the retention test resulted with a lower mean score.

It should be noted that Group C during the genetics unit, which took place after the cells unit, scored higher than Group S. Although *t* tests were run on the various groups, no statistical significance resulted.

Table 2

Combined Sentence and Clay Pedagogy Assessments in High School Biology

Group Test	N	M	Pretest Variance
Group C Pretest	96	26.93	
Group C Posttest	86	43.79	+16.86
Group C Retention	83	44.94	+18.01
Group S Pretest	85	29.82	
Group S Posttest	84	47.67	+17.85
Group S Retention	88	43.85	+14.03

A review of Table 2 indicates there is an increase in both the posttests as indicated by the plus (+) values in the final column. The final column indicates a change in mean scores between the pretest and the posttest or the retention test for each type of classroom. For example, the change in mean scores from the pretest to the posttest in the Group C was a gain of 16.86 points (M = 26.93 for the pretest and M = 43.79 for the posttest group).

Table 3 and Table 4 display the *t* statistics for the same groups. These tables necessarily include the *t* statistic, the degrees of freedom, standard deviation, mean, and *p*

value. The first table, Table 3, provides information comparing the pretest with the posttest and the second table, Table 3, compares the pretests with the retention tests. Each table includes Group S and Group C for quick comparison.

Table 3

Combined Posttest Analysis for Group C and Group S in HS Biology

Group Test	n	M	SD	*t*-test	df	Sig.
Group C Pretest	96	26.93	14.27	6.95	180	<.001
Group C Posttest	86	43.79	18.40			
Group S Pretest	85	29.82	14.85	7.43	167	<.001
Group S Posttest	84	47.67	16.36			

Note. Sig. indicates p value.

The *t* test data shown for Group S, $t(167) = 7.43, p < .001$ indicates a statistical significance. Likewise, with Group C, $t(180) = 6.95, p < .001$ indicates a statistical significance. Table 2 also shows the mean scores to be lacking in general. The mean score for the pretest was $M = 29.82$ for Group S and $M = 26.93$ for Group C. These test scores were based upon the cells test (Appendix K) and genetics test (Appendix L) which were graded out of 100 points. The same tests were utilized for the posttest and although there was a significant increase in the mean scores for Group C and Group S the scores remained below 50%.

Table 4 is identical in layout to Table 3 but contains the results of the retention tests which took place a week after the posttest.

Table 4

Combined Retention Test Analysis for Group C and Group S in HS Biology

Group Test	n	M	SD	*t*-test	df	Sig.
Group C Pretest	96	26.93	14.27	7.34	177	<.001
Group C Retention	83	44.94	18.52			
Group S Pretest	85	29.82	14.85	5.59	171	<.001
Group S Retention	88	43.85	18.51			

Note. Sig. indicates p value.

As with the posttest the results are similar to the retention test means being slightly less than the posttest results. In this case Group S class $M = 43.85$ and Group C classroom $M = 44.94$. While these results do indicate a significant increase from the pretest data, the overall results remain below 50%. The extreme statistical significance is indicated with Group S by $t(171) = 5.59, p < .001$. Group C shares extreme statistical significance with $t(177) = 7.34, p < .001$.

The change in the assessment results were similar within the analysis by cells and genetics units. Other than the increase from the pretest there was no statistical significance noted.

Although there are variances in the *t* statistic and the standard deviation is rather broad with a range from $SD = 14.27$ to $SD = 18.52$, the p value demonstrates the persistence of high statistical significance. Further comparison between the pedagogical approaches and vocabulary acquisition exist in Table 5. Table 5 includes the analysis of posttest to posttest and retention test to retention test for the two classroom groups.

Table 5

Summative Comparison between Sentence and Clay Pedagogy in High School Biology

Group Test	n	M	SD	*t*-test	Df	Sig.
Group S Posttest	84	47.67	16.36	1.45	168	0.15
Group C Posttest	86	43.79	18.40			
Group S Retention Test	88	43.85	17.98	0.39	169	0.70
Group C Retention Test	83	44.94	18.52			

The growth from the pretests to the posttests and retention tests when comparing Group S and Group C shows there is no statistical significance. The posttest comparison yielded the following result: $t(168) = 1.45, p = 0.15$. The retention test to retention test result was $t(169) = 0.39, p = 0.70$. The *t* statistic is in a more desired range, but the *p* values of 0.15 and 0.70 are definitive.

The first research question was stated as: Is there a difference in vocabulary test scores between students who study biology vocabulary using modeling clay and those who do not use clay? Table directly compares Group C against Group S within the context of a *t* test. Even though the statistical significance is not produced, the growth of scores from the Group C pretest baseline is substantial. The results from Table 1 and Table 2 both indicated the research question was proven by the posttest and retention test results. Growth within each unit and as a combination aggregate support the use of clay as a pedagogical methodology. The results of any statistical significance are shown when the data between pretests and either posttests or retention tests were assessed as in Tables 3 and 4. Comparison of the results between the two units of the study does demonstrate consistency within the units validating the assessments and methods used. Further analysis by gender reveals additional benefits from the study.

Quantitative Data Analysis by Gender

Further quantitative analysis was undertaken with regard to gender. The following figure, Figure 6, displays the most pertinent data regarding comparisons between the performance of the males and females in the study with regard to Group C and Group S. The data shown, in bar graph format, are the increases in mean scores from the pretests. For example the first two columns show males in Group S had a mean score increase of 18.52 points from the pretest to the posttest and a 14.04 increase from the pretest to the retention test. One important piece of information to note is Group C scored higher increases than the sentence group for males. Another important factor is the females in Group C were the only group to improve after the retention test which may lead to further inquiries regarding kinesthetic learning and memory.

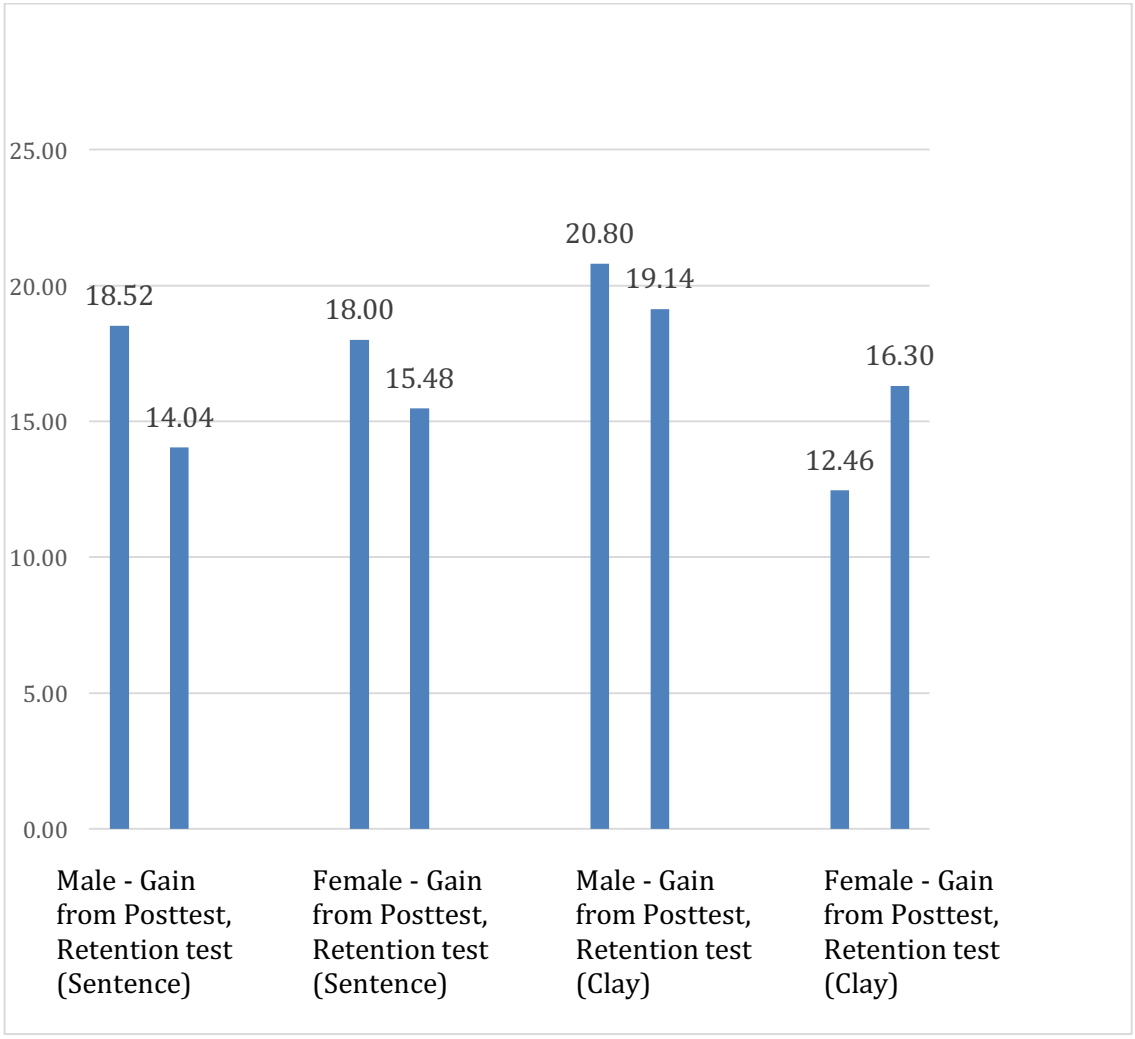

Figure 6. Mean increase from pretest scores by gender and test.

The following Tables include a breakdown of the males and females within Group C and Group S by unit. The cells unit is analyzed first in Table 6. As with the summary data the male breakdown in the cells unit results included an increase from the pretests but there was no significance between Group C and Group S.

Table 6

Male Assessment Results from Cells Unit by Pretest, Posttest, and Retention Test

	n	M	SD
Group C Assessments			
Pretest	20	27.50	12.82
Posttest	16	36.88	18.70
Retention Test	17	41.18	19.25
Group S Assessments			
Pretest	23	29.57	11.27
Posttest	19	48.16	15.47
Retention Test	25	47.20	17.68

A similar analysis summary of the males was made for the females in Table 7. Table 7 was constructed using data from the cells unit. A comparison between the males and females within Group C does show the females retention test scores increased in both Group C and Group S while they only increased in Group C for the males.

Table 7

Female Assessment Results from Cells Unit by Pretest, Posttest, and Retention Test

	n	M	SD
Group C Assessments			
Pretest	26	26.73	13.49
Posttest	24	36.04	13.67
Retention Test	24	43.54	16.05
Group S Assessments			
Pretest	20	26.50	11.25
Posttest	21	41.43	13.67
Retention Test	20	45.75	14.80

Tables 8 and 9 are identical to the previous two tables except they contain data from the genetics unit, or the second unit of the study. The information is very similar

despite a change in the assessment instrument. The similarity of results bolsters the validity for the instruments and the study itself.

As with the previous two tables the data here begins with male analysis in group C and then Group S. The female data, by group, follows in Table 9. There were several items worthy of comment within Table 8. The first point is the posttest scores in Group S dropped below the pretest scores. However, the retention test scores exceeded both the pretest and posttest scores. Group C scores were higher than Group S scores except for the pretest. Despite the pretest scores in Group C being ten points lower than the scores in Group S, the Group C participants outscored Group S.

Table 8

Male Assessment Results from Genetics Unit by Pretest, Posttest, and Retention Test

	n	M	SD
Group C Assessments			
Pretest	28	23.57	12.54
Posttest	27	52.04	18.36
Retention Test	24	47.50	21.06
Group S Assessments			
Pretest	17	33.82	23.57
Posttest	18	20.74	18.36
Retention Test	15	42.33	25.97

The final table comparing Group C and Group S in the genetics unit was Table 9. Table 9 shows the results of the females in the study. The data showed the females in Group C and Group S did not score as high on the retention test as the posttest. However, the females in Group C did score nearly six points higher on the retention test than the females in Group S despite the pretest score being less than two points higher. There was a net gain for Group C of almost four points.

Table 9

Female Assessment Results from Genetics Unit by Pretest, Posttest, and Retention Test

	n	M	SD
Group C Assessments			
Pretest	21	31.67	18.19
Posttest	17	48.53	18.60
Retention Test	17	47.65	18.38
Group S Assessments			
Pretest	26	28.85	15.12
Posttest	23	50.22	12.20
Retention Test	26	41.35	15.33

Table 10 and Table 11 include the *t* statistics, degrees of freedom, and *p* values for a more complete analysis. Table 10 details the increases and the information between the pretests and the posttests. Then the analysis between the genders and the various methods is completed as well. The statistical analysis within Table 10 displays comparisons between male and female posttests in sentences with a $t(79) = 1.10, p = 0.28$ and with the clay pedagogy $t(80) = 1.27, p = 0.21$. The intent of the conducted analysis was to determine any support of the hypothesis postulated in the first research question regarding variance in pedagogical methodologies. While there is a notable difference in the mean ($M = 49.86$ and $M = 46.54$) for the males in sentences and clay respectively and for the females in sentences and clay ($M = 45.78$ and $M = 41.40$), the p values indicate no significance. Also, worthy of note is the SD for the females is lower indicating a lack of variance in test scores.

Table 10

Posttest Analysis of Group C and Group S in High School Biology by Gender

	n	M	SD	*t*-test	df	Sig.
Male Group S Pretest	41	31.34	16.43	4.71	75	< .001
Male Group S Posttest	36	49.86	18.11			
Female Group S Pretest	45	27.78	13.21	5.97	88	< .001
Female Group S Posttest	45	45.78	15.34			
Male Group C Pretest	47	25.74	12.67	5.98	84	< .001
Male Group C Posttest	39	46.54	19.40			
Female Group C Pretest	47	28.94	15.77	3.57	88	< .001
Female Group C Posttest	43	41.40	17.37			
Male Group S Posttest	36	49.86	18.11	1.10	79	0.28
Female Group S Posttest	45	45.78	15.34			
Male Group C Posttest	39	46.54	19.40	1.27	80	0.21
Female Group C Posttest	43	41.40	17.37			

Table 11, below, is identical in layout to Table 10 excepting the substitution of the retention test data for the posttest data. The statistical data contained in Table 11 displays the comparison between males and females via the pedagogical use of sentences as $t(84) = 0.54, p = 0.59$ and with the clay pedagogy $t(80) = 0.09, p = 0.931$. These statistical results indicate no significance or verification of the research question.

Table 11

Retention Test Analysis of Group C and Group S in HS Biology by Gender

	n	M	SD	t-test	df	Sig.
Male Group S Pretest	41	31.34	16.43	3.36	79	< .001
Male Group S Ret. Test	40	45.38	20.98			
Female Group S Pretest	45	27.78	13.21	5.20	89	< .001
Female Group S Ret. Test	46	43.26	15.10			
Male Group C Pretest	47	25.74	12.67	5.37	86	< .001
Male Group C Ret. Test	41	44.88	20.33			
Female Group C Pretest	47	28.94	15.77	4.67	86	< .001
Female Group C Ret. Test	41	45.24	16.95			
Male Group S Ret. Test	40	45.38	20.98	0.54	84	0.589
Female Group S Ret. Test	46	43.26	15.10			
Male Group C Ret. Test	41	44.88	20.33	0.09	80	0.931
Female Group C Ret. Test	41	45.24	16.95			

Despite the lack of any statistical significance, there remains a similar outcome with regard to standard deviation as the female scores are lower indicating a tighter scoring range. Inconsistency with the posttests does arise with the mean scores. While the posttests showed males scored higher on the posttest for both the sentence and clay pedagogical methodologies, the retention test results are split. The males did score higher with sentences ($M = 45.38$) than the females ($M = 43.26$). The females, however, scored higher with the clay on the retention tests ($M = 45.24$) than the males ($M = 44.88$). The difference is noted, but the difference, although unique, is less than one percent.

Survey Data Analysis

At the end of each unit, cells or genetics, Likert-style surveys were completed by the students in a whole group setting. The surveys, comprised of 25 questions, were used

by Group S and were the same after each unit (see Appendix G). The surveys used by Group C contained 30 questions (see Appendix F).

The intention behind the surveys was to have the results provide data to answer, at least partially, the second research question: What are students' and teachers' perceptions regarding the use of modeling clay for biology vocabulary acquisition? By interviewing the students after both the cells and genetics unit the perceptions could be assessed to a great degree. Additionally, the repetition of the surveys within the study aided in reliability.

The surveys' complete range included the following responses: Strongly Agree, Agree, Neither Agree nor Disagree, Disagree, and Strongly Disagree. The tabulation of the surveys included the transference of agreement and disagreement with numerical values. Strongly Agree was converted to a 1 and Strongly Disagree was valued at 5. The mean values were calculated from the aggregate scores of all Group C and Group S classes.

Lack of agreement or disagreement, i.e. scores close to 3, posed no statistical interest for the study. Any significance to the study or research was found in the responses to the survey items. The analysis included commentary upon responses, the lack of expected responses, and a comparison between similar questions of Group C surveys and Group S surveys.

Table 12 includes the mean scores of all survey items with complements or mirror questions. For example, the first survey item on the Group S survey was, "The clay helped me understand the words," whereas the mirror question on the Group S survey was, "The definitions and sentences helped me understand the words." Table 12 includes

the survey question number from the Group C survey. In the example, the mean score for clay $M = 2.72$. The mirror item in the control group was $M = 2.24$. The variance in the mean scores leads to the conclusion that the students possessed more agreement the sentences helped them understand the words than the use of clay creations in forming definitions. Table 12 includes twenty-four questions which all had mirror questions.

Table 12

Survey Mean Scores for Mirror Questions

	Group C			Group S		
	N	M	SD	N	M	SD
Q1	81	2.72	1.063	78	2.24	0.900
Q2	81	2.65	1.074	78	2.53	1.016
Q3	81	2.86	1.202	78	2.90	1.027
Q4	81	2.69	1.056	78	2.69	1.036
Q5	81	2.60	1.033	78	3.01	1.051
Q6	81	2.56	1.095	78	3.01	1.051
Q7	81	2.93	1.104	78	2.86	1.016
Q8	81	3.11	1.245	78	2.91	1.219
Q9	81	3.07	1.034	78	3.29	1.046
Q10	81	2.94	1.155	78	2.46	0.848
Q11	81	2.58	1.047	78	2.64	1.006
Q12	81	2.84	1.066	78	2.51	0.977
Q13	81	2.38	1.079	78	2.56	1.202
Q14	81	2.86	1.191	78	2.71	1.058
Q15	81	3.00	0.949	78	3.45	1.124
Q16	81	2.62	1.067	78	3.67	1.234
Q17	81	2.83	0.959	78	3.19	1.249
Q18	81	3.31	1.103	78	2.58	1.013
Q19	81	4.10	0.982	78	2.81	1.070
Q21	81	2.91	1.142	78	2.09	1.059
Q22	81	2.83	1.104	78	2.51	0.818
Q23	81	3.02	1.000	78	3.10	1.123
Q24	81	2.64	1.016	78	2.63	0.968
Q25	81	2.86	1.022	78	2.64	1.032

Notable differences in the treatment and control survey mean scores include items 8, 19, 21 and 22. The use of clay was perceived as being more difficult than the writing

of sentences. While both sets of survey responses tended towards disagreement, the physical use and manipulation of clay and difficulties were clearly indicated. This perception of difficulty was also enhanced by the responses to item 19 on the Group C survey which mirrored item 20 on the Group S survey. The item was written to determine mastery over the use of clay or the writing of sentences. From the survey data, it was clearly shown the students lacked more confidence in the use of clay than writing sentences. However, the following item, item 21, indicates the students were less bored with clay than the writing of sentences. Finally, students seemed to agree sentence writing presented more of a challenge than the use of clay as indicated by the mean scores on item 22.

Independent t tests were run on the mirror survey questions and five survey questions were noted as having statistical significance with a p value less than 0.05. The survey questions were included in Table 13 below.

Table 13

Combined Survey Mirror Questions with Statistical Significance

Cells	Unit	n	M	SD	Sig.	*t*-test	df
Q1	Clay	81	2.72	1.063	0.030	-3.018	157
	Sentence	78	2.24	0.900			
Q10	Clay	81	2.94	1.155	0.037	-2.958	157
	Sentence	78	2.46	0.848			
Q15	Clay	81	3.00	0.949	0.013	2.724	157
	Sentence	78	3.45	1.124			
Q17	Clay	81	2.83	0.959	0.002	2.072	157
	Sentence	78	3.19	1.249			
Q22	Clay	81	2.83	1.104	0.047	-2.034	157
	Sentence	78	2.51	0.818			

Note. Sig. indicates p value.

The five questions that had statistical significance as determined by independent *t* tests included Q1 which stated the activities in the classroom for the study in both Group C and Group S helped the students. Q10 incorporated the visual aspect of working with both clay and the writing of sentences. Q15, which included responses indicating disagreement was concerned with the desire of students to complete more words than were on their vocabulary lists. Q17 indicated that students in Group C looked forward to the activity more than those in Group S. The last question, Q22, stated that each word presented a new challenge.

Table 14

Survey Mean Scores for Cells Unit Mirror Questions

	Group C			Group S		
	N	M	SD	N	M	SD
Q1	39	2.72	1.146	38	2.26	0.795
Q2	39	2.54	1.120	38	2.71	1.011
Q3	39	2.85	1.204	38	2.87	1.095
Q4	39	2.59	1.093	38	2.82	1.136
Q5	39	2.54	1.022	38	3.16	1.079
Q6	39	2.44	1.142	38	3.11	0.981
Q7	39	2.90	1.095	38	2.97	0.972
Q8	39	2.92	1.384	38	3.03	1.262
Q9	39	2.77	1.038	38	3.34	0.966
Q10	39	2.85	1.268	38	2.63	0.883
Q11	39	2.59	1.069	38	2.71	1.088
Q12	39	2.85	1.136	38	2.55	0.950
Q13	39	2.46	1.072	38	2.45	1.179
Q14	39	2.95	1.213	38	2.82	0.982
Q15	39	3.03	0.932	38	3.63	1.025
Q16	39	2.41	1.069	38	3.63	1.195
Q17	39	2.82	1.023	38	3.39	1.079
Q18	39	3.31	1.128	38	2.63	1.149
Q19	39	4.23	0.931	38	2.82	1.087
Q21	39	2.90	1.071	38	2.08	1.038
Q22	39	2.90	1.119	38	2.55	0.645
Q23	39	3.21	1.056	38	3.18	0.896
Q24	39	2.69	1.080	38	2.79	0.963
Q25	39	2.67	1.132	38	2.75	1.062

Further investigation of the data was undertaken with regard to the cells unit and the genetics unit. Table 14, contains the mirror questions broken down as the cells unit. The same mirror survey questions are included as in Table 12 with the values relevant to the unit. Table 15 contains a similar data set with the genetics unit responses.

Table 15

Survey Mean Scores for Genetics Unit Mirror Questions

		Group C			Group S	
	N	M	SD	N	M	SD
Q1	42	2.71	0.995	40	2.23	1.000
Q2	42	2.76	1.031	40	2.35	1.001
Q3	42	2.88	1.214	40	2.93	0.971
Q4	42	2.79	1.025	40	2.58	0.931
Q5	42	2.67	1.052	40	2.88	1.181
Q6	42	2.67	1.052	40	2.93	1.118
Q7	42	2.95	1.125	40	2.75	1.056
Q8	42	3.29	1.088	40	2.80	1.181
Q9	42	3.36	0.958	40	3.25	1.127
Q10	42	3.02	1.047	40	2.30	0.791
Q11	42	2.57	1.039	40	2.58	0.931
Q12	42	2.83	1.010	40	2.48	1.012
Q13	42	2.31	1.093	40	2.68	1.228
Q14	42	2.79	1.180	40	2.60	1.128
Q15	42	2.98	0.975	40	3.28	1.198
Q16	42	2.81	1.042	40	3.70	1.285
Q17	42	2.83	0.908	40	3.00	1.377
Q18	42	3.31	1.093	40	2.53	0.877
Q19	42	3.98	1.024	40	2.80	1.067
Q21	42	2.93	1.218	40	2.08	1.095
Q22	42	2.76	1.100	40	2.48	0.960
Q23	42	2.85	0.926	40	3.03	1.310
Q24	42	2.60	0.964	40	2.47	0.960
Q25	42	3.05	0.882	40	2.55	1.033

The responses from both Table 14 and Table 15 were further analyzed for statistical significance. A *t* test was run and the following information includes the results. Note there were differences between the combined results and the results by unit. Q1 was included in both tables as well as Q10, Q17, and Q22. The other survey

questions worthy of note include questions 16 and 23 from the genetics survey. Q16 was a question regarding a desire to remain after school or to stay late to write more sentences in Group S or work more with the clay in Group C. The responses from the genetics unit indicate the students in Group C were more willing to remain than those in Group S. Q23 stated the students in either group did not find the activities assisted with clarification of the vocabulary word. As with the previous question, Q16, the students in Group C had a more positive outlook on the study procedures than those students in Group S.

Another point worthy of note is all the questions in the cells unit denoting statistical significance were included in the combined data analysis as significant. Only one of the questions in Table 16 under the genetics unit was also in the combined data. Likewise, no questions of statistical significance repeated in the cells unit and genetics unit.

Table 16

Survey Mirror Questions with Statistical Significance by Cells and Genetics Units

Cells Unit		n	M	SD	Sig.	*t*-test	df
Q1	Clay	39	2.72	1.15	.002	-2.019	75
	Sentence	38	2.26	0.80			
Q10	Clay	39	2.85	1.27	.010	-0.860	75
	Sentence	38	2.63	0.88			
Q22	Clay	39	2.90	1.12	.009	-1.651	75
	Sentence	38	2.55	0.65			
Genetics Unit		**n**	**M**	**SD**	**Sig.**	***t*-test**	**df**
Q16	Clay	42	2.81	1.04	.010	3.455	80
	Sentence	40	3.70	1.29			
Q17	Clay	42	2.83	0.91	.002	0.650	80
	Sentence	40	3.00	1.38			
Q23	Clay	42	2.86	0.93			
	Sentence	40	3.02	1.31			

The following table, Table 17, provides a collection of all survey questions which were written without a mirror question. The first survey question from Group C had no similar question in the Group S survey and the last question has no mirror question in the Group C survey.

Table 17

Survey Questions without a Mirror

Group C Survey Questions
Q20. I could visualize what I wanted to make with the clay before I started.
Q26. I could not shape the clay into what I wanted.
Q27. I played with the clay more than I needed to.
Q28. The clay was messy.
Q29. I did not like cleaning up the clay area.
Q30. I had to work with the clay for a while until an idea came to mind
Group S Survey Questions
Q11. I wrote more sentences with vocabulary words than needed

The first section from the Group C survey contains, within the six total items, five dealing with the physical manipulation of the clay. Question 20 does not concern the physical aspects of working with clay directly. However, items 26 through 30 were asked to unveil insights regarding potential difficulties in using modeling clay. The responses were favorable. While students had some rather slight agreement with not being able to shape the clay as desired and playing with the clay more than needed, they did not seem to mind cleaning up the clay. There is a very slight agreement that the clay was messy. There is agreement between visualizing what was being created in clay and not having to work with the clay for long before an idea came to mind.

The sole question from the control group inquired as to the use of additional sentences and the result $M = 2.88$, indicating a very slight agreement but overall neither agreement nor disagreement.

A comparison between the mean scores of the complementary items proved to be a bountiful source of information from the sets of surveys. Additionally, the inspection of the results included notice of outliers. The scores ranging from 1 to 5 had the midpoint of 3 which represented neither agreement nor disagreement. Only one question resulted in a mean score that lay outside the averages of two or four, thus a wider range of responses was considered with outliers indicated by a mean below 2.5 or above 3.5. There were eight survey questions falling within this range. The eight items were, coincidentally, evenly divided between the clay and the sentence scores. The eight survey questions so discovered are included in Table 18.

Table 18

Survey Outlier Questions with Mean Scores

Group C Survey Questions	M
Q16: I stayed late or after school to work with the clay. (C)	4.10
Q24: Using the clay helped me with spelling. (C)	3.51
Q28: The clay was messy. (C)	2.38
Q22: Every word presented a new challenge. (C)	2.27
Group S Survey Questions	
Q10: Writing sentences helped me picture the meaning of the vocabulary words more clearly. (S)	M 2.46
Q17: I stayed late or after school to write sentences. (S)	3.67
Q1: The definitions and sentences helped me understand the words. (S)	2.24
Q21: Writing sentences was boring after a while. (S)	2.05

Notes. The survey items ranged from 1 to 5.

The survey questions were created with a comparative duality in mind. In other words, as often as possible, the same question was asked for both groups. One of the survey questions for the clay group (Question 16) and for the sentence group (Question 17) was: I stayed late or after school to work with the clay/to write more sentences. The response for the clay students was $M = 4.10$ (disagree), while the sentence group scored $M = 3.67$ (disagree).

The other six questions regarding the student survey were not as distant from the normal line of a 3 or a neither agree nor disagree. The only other survey question, with $M = 3.51$, resulting in a disagree status was: Using the clay helped me with spelling. The other five questions from the survey resulted in an affirmation or agreement. The next question furthest from the norm scored $M = 2.05$ and was from the sentence survey: Writing sentences was boring after a while. In contrast to this survey question, the clay pedagogy question 22 (Every word presented a new challenge) had a positive response with $M = 2.27$.

Two of the remaining three survey questions were from the sentence classroom. Questions 1 and 10 from the control group survey had respective means of $M = 2.24$ and $M = 2.46$. The first question was: The definitions and sentences helped me understand the words. The tenth question was: Writing sentences helped me picture things more clearly.

The final question with a mean worthy of note was question 28 on the clay, or treatment, group survey: The clay was messy. The survey item had $M = 2.38$. The value, although definitely one in accord with an affirmation, is not an overly compelling average by any means.

The survey questions were all created with consideration of the purpose of discovering not merely agreement or disagreement with the item, but a point of intent as well. Specifically, each question was written with a desire to note the effectiveness perception of the student, or the motivation of the student, or a challenge or benefit aspect as well.

With these eight questions, further scrutiny reveals the effectiveness of the program from the students' viewpoint. Looking at effectiveness it is understood that clay was not effective with spelling while writing sentences was effective in helping students picture things more clearly. Also, using definitions and writing sentences was effective in vocabulary pedagogy. As far as perception and motivation while the sentence writing was seen as boring after a while, the clay was perceived as presenting new challenges. Lastly, the motivation, as it relates to challenges or benefits, was limited as neither the clay group nor the sentence group desired to remain late or after school to continue in completing the assignments in the study.

As stated the purpose of the surveys within the study was to capture the student participants' perceptions regarding the use of clay, and subsequently the use of sentences. The eight survey items, considered outliers, have noted positive and negative points of vocabulary pedagogy postulated by the study's second research question.

Interview Data Analysis

Following the biology cells unit, an interview was conducted with the participating teacher. Upon completion of the biology genetics unit, another interview was conducted with the same set of questions. The interviews included ten questions which were used in every interview. There were no other interview participants beyond

the researcher and the participating teacher. The purpose of the ten questions was to obtain data to answer the second and third research questions. The second research question was: What are students' and teachers' perceptions regarding the use of modeling clay for biology vocabulary acquisition? Although the answers to the student surveys did provide some response data, the second research question contains a portion of inquiry for the teachers involved in the study too. The third research question was: What are the challenges and benefits of using modeling clay for biology vocabulary acquisition in the classroom? Thus, the interviews were aimed at obtaining answers regarding not merely the effectiveness of the study, but information concerning the execution of the study in the classroom and any information about planning for the use of clay.

The interviews took place during two different timeframes as one group of students completed the study in the Spring of 2018 while the other classes completed the survey in the Fall of 2018. The first participating teacher interviewed on 4/11/18 and then on 5/22/18. The second teacher interviewed on 8/24/18 and 10/5/18.

As previously mentioned each teacher was certified and practicing in Southwest Georgia in a public school. They each had taught both science and biology for years. The researcher took notes and recorded the interviews. There were ten interview questions (see Appendix I) asked during each interview. The following analysis will include the responses from each participating teacher in the cells unit followed by the genetics unit. Thus, the responses will be from 4/11/18 and then 8/24/18 and then the genetics unit responses of 5/22/18 and 10/5/18. With this arrangement, the responses will alternate between the teacher who conducted the study in the spring semester and the teacher who conducted the study in the fall semester. As noted earlier, the first teacher

oversaw the study in two classes and the later participating teacher oversaw three classrooms. Bearing this in mind, the data is not as diverse as could have been with different teachers for each classroom. Nevertheless, the teachers were able to see the entire process and contribute at a potentially more insightful level.

The responses for the questions were culled through and the salient points are contained herein. Although nine of the ten questions were open-ended questions a few of the open-ended questions could be answered with a list or stating a few considerations. The teacher from the spring semester shall be referred to as Teacher A with the fall semester teacher being noted as Teacher B.

The first question was: How did using clay affect student learning? Teacher A responded by stating, "The study [*sic*] made them think about how they would represent the definition, extra thinking may have helped. They learned something." Teacher B stated, "At first they were excited to play, then bored. Twenty words may have been a bit much. I think the models were creative." After the genetic units, Teacher A, who works in a block schedule school stated, "They did a whole day to work on it. It helped them this time. It was better doing it all in one day. More focused." Teacher B's genetics unit response was similar to her first, "Just by observation; very excited first time, the clay was a little hard and they got a little bored. Not much interested."

The second question was: How was the use of clay different for your students than other methods of vocabulary instruction? Teacher A began by saying, "Initially not sure what to do. In their head made sense, but not in the clay. They never had to do it before." Teacher B's reply was that the students were excited to play adding, "different students had different styles. And they did okay with the sentences." After the genetics

unit, Teacher A replied that the novelty was interesting for them. And that some of the students were "really into it.". A follow-up question was asked: "How many into it?" To which she replied, "A half or a quarter really into it." Teacher B responded after the final genetics unit that the students were interested and enjoyed it. The students also enjoyed molding the clay, but not able to make molds quickly. Completing a model took two days in some cases.

The only closed-ended question was the third question: Was classroom management different when students used the clay? Thus, the follow-up question, "How so," was added. After the cells unit, Teacher A replied that an adjustment period was needed as well as "some discipline" with the clay was needed. She had to keep them on track as they were creating flowers and other items with the clay. Additionally, when it was understood what was involved there was some complaining about "how much work it was." In contrast, Teacher B stated they loved the hands on. The students were more involved, focused, and she had no issues. The second round of interviews with Teacher A revealed that some students still desired to play with the clay and even throw it. Teacher B maintained that the students were actively engaged.

The fourth question is, for all intents and purposes, two questions: What were the challenges to using clay in the classroom and how were they met by you? The concerns voiced by Teacher A involved the physical use of clay. The clay was hard to work with. It was hard to break up the clay. Smaller sections were easier. It gets all over everything. Green gets on hands. Had to work harder on washing hands. Teacher B stated there were not really any challenges, adding that the clay was hard. After the genetics section, Teacher B voiced the same concerns with the hardness of the clay. Teacher A did not

mention the hardness on the second round, but she said it was easier to do it all in one day. There was carry over. But it did not involve all the setup and breakdown.

The verbiage of question five includes a query about the benefits of the study: What were the benefits of using clay in the classroom? Teacher A mentioned that the benefits included the study being different. Some kids were jealous they didn't get to use it. The different method (from sentences) was exciting. They got to be creative initially but got tired. It took longer than the other method (sentences) and the novelty wore off. The students suggested doing more in one day as the starting and stopping took too long. Teacher A told them "I would think about that." Teacher B reiterated from an earlier answer that the students liked the clay, the hands-on, and making models, being creative. After the genetics unit, Teacher A mentioned a benefit being that the students were exposed to vocabulary not yet covered. Teacher B mentioned that the students were actively engaged. She added that some students were critically thinking about what to make. Some referred to the textbook, while others were creative.

The sixth question was geared to teacher preparation: How did you prepare for your lessons when clay use was in your lesson plan? Teacher A stated the study was just something tacked onto the front of the lesson. She mentioned that genetics will be more time appropriate with her lessons and the cells unit timing threw some students off. Teacher B stated the vocabulary was hands-on and wrote "research" in lesson plans. For the genetics unit survey, Teacher A simply set aside a day for the study. Teacher B said, "Like hands-on and differentiated instruction, clay more interpersonal, can use it."

The seventh question was: What changes should be made with the study as you see it? Teacher A at first said "I don't . . . makes sense to me. Some kids were wanting

to switch. Some wanted to with the method they were on." She added that having the whole class do one method would be better. As far as any physical changes she recommended a spray bottle for cleaning as the wipes provided were used up too fast. Lastly, she said, "align timing with the units and vocabulary." Teacher B said the vocabulary was merely descriptive and maybe having the students do analogies in clay would be better. They made copies of what was in the text. Not as creative, simply used pictures. Needed more direction. After the genetics unit, Teacher A again stated that there were no changes needed. She did mention that it was better for the students to see both sides of the study. She added, "low achievers worked more diligently on the clay. The clay helped them. And they were more inclined than writing." Teacher B suggested doing five words at a time, break it up.

The eighth question dealt with the physical arrangement of the classroom: How were the logistics of the classroom set-up altered when using clay? Teacher A and B both said there were no changes to the room layout and the students simply worked at their desks.

The ninth question was to be asked if the same teacher oversaw the control and treatment classes. This was the case for both teachers as they each oversaw the study in more than one class and with each type of group. The ninth question was: How would you compare learning between the treatment class and control class? Teacher A began by saying that she did not know the results yet. Adding, "I think the sentences group had to come up with three sentences or meanings as opposed to one way to show it in clay. One definition is shown, whereas sentences were learning the word three ways. Sentence group was done a lot faster." Teacher B said the hands-on was appreciated, more

engaging, completely hands on. The other group was bored. Post genetics, Teacher A reiterated the sentence group had to get more information than the clay; three sentences over just one clay representation. Wager that one sentence to one clay, maybe better with the clay, but three to one the sentences would do better. Teacher B again stated the students were "happy with the clay, but the clay was hard. Other way was okay." "Needed to not use the text but be creative." "The boys more into hands-on but they tried to copy."

The tenth question was asked to explore the possibilities of using clay beyond a biology setting. The question was: How could clay be used in other disciplines or subjects? Teacher A mentioned she could see it being done in foreign languages, "This is your Spanish word, do it in clay." Social studies could use it to make battle scenes. Literature she was unsure about it, but added, "math lends itself to manipulatives. Graphs in clay. Think more than copy a graph." The researcher followed up asking about other sciences and Teacher A responded with anatomy and anatomical parts. And she could totally see it in chemistry and physical science with ionic bonding. Teacher B mentioned English as models could be settings. CTAE (Career, Technical, and Agricultural Education), engineering classes, parts of computers. Adding the ideas that students could be more productive in class, it would help them. For the genetics survey round, Teacher A said she had the same ideas as the previous interview. Teacher B said the clay might work in ELA (English Language Arts) settings for novels (as mentioned prior) and she added math for lower grades and models in engineering (as previously mentioned).

Finally, the interviews were ended with the query, “Anything else to offer or comment?” This did not solicit a response from either Teacher A or B during the cells unit. And Teacher B did not comment after the genetics round, but Teacher A did. Her responses could have been included under Question 7 regarding changes to the study. Teacher A replied, “Maybe more rollers. Scissors to cut clay. Can’t use knives, maybe plastic knives. Rulers. Rather work with playdough, but this won’t dry out,” adding finally, “nobody made inappropriate things.”

There were four themes identified from the responses of the participating teachers. The following table, Table 19, included themes repeated for at least two questions. For example, Teacher A was asked question two: “How was the use of clay different for your students than other methods of vocabulary instruction?” The interview notes or transcript contained the quote “they were excited to play [with clay].” The second interview from Teacher A may have included the response, “the novelty [of working with clay] was interesting for them.”

Table 19

Themes by Question from Teacher Interviews

Theme	Comments
Clay Harness/Difficulty	Initially hard to work with. Breaking up was hard.[A4-4/11] Scissors to cut clay, can't work with knives, but maybe plastic knives. Rather work with playdough but this won't dry out.[A11-5/22] Hard clay but overall they enjoyed it.[B4-8/24] The clay was a little hard.[B1-10/5] Little hard, expecting play dough.[B4-10/5] Happy with the clay but it was hard.[B9-10/5]
Novelty/Excited re Clay	Different method was exciting.[A5–4/11] At first they were very excited to play [with the clay].[A1–5/22] Novelty was interesting for them.[A2–5/22] They were excited to play [with the clay].[B2–8/24] Very excited the first time.[B1–10/5] Enjoyed it.[B2–10/5]
Engaged/Focused on Clay	Some were really into it [clay].[A2-5/22] They were more involved. Focused on the models. Loved the hands on.[B3-8/24] They like the hands on.[B5-8/24] Appreciate hands on. More engaging.[B9-8/24] Actively engaged.[B3-10/5] Actively engaged.[B5-10/5] Appreciate hands on. More engaging.[B9-8/24] Engaged more with the clay. Boys more into hands on.[B9-10/5]
Bored/Too much work	Complaining about how much work it [clay] was.[A3-4/11] Hard to work with.[A4-4/11] Got tired. Took longer [than sentences].[A5-4/11] Bored. Maybe 20 words was too much.[B1-8/24] They got a little bored. Not that much interested.[B1-10/5] Five words at a time, break it up.[B7-10/5]

Note: The comments were annotated as teacher (A or B) followed by the question number (1 through 11) and then date. Thus, A2-5/22 would be a comment from Teacher A in response to question 2 on May 22nd.

While overlapping similarities and saturation exist for Question 10 (How could clay be used in other disciplines or subjects?), the responses were not noted within the table. The nature of the question is an extrapolation of the existing study and does not

have any bearing upon the results and was included for potential future duplication or augmentation of the study. Table 19 presents themes, down the left column, and then the grid of questions during which the theme was mentioned. The table includes all four interview dates. Note the days between the interviews is the time from the completion of the cells unit and the end of the entire study or the genetics unit. The days lapsed, 41 days accumulated between the Teacher A interviews, and 42 days for Teacher B, do not include the time spent on the cells unit. Both participating teachers had a number of weeks between the interviews. Teacher A interviews took place after work at a coffee shop, while Teacher B interviews took place in her classroom.

Based upon the data present in Table 19 the main theme which reoccurred had to do with the hardness or difficulty physically manipulating the clay, the initial novelty of using clay in the classroom, the vocabulary pedagogy involving the use of kinesthetic, and boredom or overuse of the clay.

The hardness of modeling clay was a concern for the teachers as the students had a real-world problem. The use of rulers and rollers assisted in the manipulation of the clay. Also, the teachers, at times, reverted to scheduling more time at once to avoid the start and stop and the subsequent hardening of the clay. Additionally, teachers were instructed to allow the students to reuse portions from previous clay representations. This point was reiterated to the participating teachers. Physical difficulties of the clay use were mentioned by Teacher A once during Question 4 (regarding challenges to using clay) and in both interviews with Teacher B. The point was also made by Teacher B during Question 1 about the clay affecting student learning, and Question 9 concerning the differences in the treatment and control pedagogy. Teacher A mentioned it as a

response to Question 11 where the researcher asked if there was anything else to consider.

The next recurring theme, students being excited about the novelty of working with clay, was mentioned in response to Question 5 after the cells unit by both teachers and then by both teachers in response to Question 1 and Question 2. Question 5 dealt with the benefits of the study whereas Question 2 asked about the differences between clay and other pedagogical methodologies. The interest of the use of clay did maintain, for some portion an individually captive audience. The words and phrases included under this theme included: novelty, creativity, really into it, excited, interested, and liked. The teachers did not repeat the theme under the same questions during the two interviews. The only similar word repeated under the same question was the use of the word excited, which occurred as a response to Question 5 in both Teacher B interviews.

The third discovered theme dealt with student engagement. While the nature of clay is kinesthetic it may not necessarily guarantee engagement. Of note is also the fact that the teacher with fifteen years of science teaching experience mentioned the benefits of engagement seven times. The responses included such verbiage as interested, enjoyed, involved, actively engaged, boys more into hands-on, worked more diligently, hands-on was appreciated. Teacher A mentioned in the second interview that the students were really into it adding that about half or a quarter of them were.

The final theme noted was the boredom or it took too much work to use the clay. This was mentioned by both participating teachers at least once in every interview. Teacher A mentioned it in Question 3, Question 4 both times, and in Question 5, while Teacher B mentioned it in Question 1 both times, Question 2, and in Question 7. Note

the topic arose for each teacher, however, it was not in response to the same questions. The theme included the following phrases and words: bored, tired of, little bored, completion in smaller sections, break it up, some models took two days, twenty words was too much.

A close read of the responses unveiled the aforementioned themes. Two of the common themes were negative in nature. These two included one which was specific to the physical manipulation and hardness of the clay. The other theme was the amount of work needed or the number of words used in the study. On the positive side were the two themes dealing with how students were engaged and involved with the methodology and the excitement related to the approach being new or a novelty.

Chapter V

DISCUSSION

This chapter includes a discussion of the study including the findings, the results, and the recommendations for future research. The following discussions revolve around the design of the study, revisited literature, methods, limitations, the findings, and implications of the study for future research.

The intention of the study was to discover effective vocabulary instruction using modeling clay. Division of learning styles and the use of tactile methodologies have always been a point of personal curiosity. Conducting a study that entailed the use of modeling clay seemed a good way to bolster the previous experiences or negate them as a valid classroom procedure. The positive results of the study have successfully satiated this curiosity.

The second initiative included conducting a study in the classroom. Having read a number of articles wherein studies took place in the classroom, especially overseas, it seemed only fitting to conduct a study with a novel approach to learning in local schools. The study took place in local schools via solicitation of friends of known individuals in the local scholastic region. The number of denials by superintendents, principals, and teachers was not tracked in great detail. Those who eventually participated were professional, forthright, and persistent. There were initially four teachers from three different school districts who agreed to partake in the study. Two of the willing teachers were instructed by their administration to not partake in the study. The claim was a lack

of time due to a hurricane having shortened days in school as well as not wanting to take time away in the classroom itself from what was already planned. This was also affected by the schedule of obtaining IRB approval. The approval of the study from the IRB began in August of 2017 and with the follow-up requests and adjustments to the study resulted in not receiving approval until January of 2018 (See Appendix H). However, the study was conducted without any ethics or disciplinary issues with participating students or faculty. Upon receipt of approval in January there were two teachers scheduled to partake in the study. While one started and finished, the second teacher, despite approval from administration and having received all needed materials, felt taking part in the study was too much and subsequently returned all the materials and did not finish. Thus, a second search for participants was undertaken in the summer of 2018 and fortunately, a teacher was found who was teaching three biology classes. The execution of the study and the resulting data was obtained from the teacher who completed the study in the Spring of 2018 and the second teacher in the Fall of 2018. What follows are testing data, survey data, and interviews from those teachers and their students.

Purpose of the Study

The purpose of the study was to find the best way to teach vocabulary. There are many ways utilized, considerations and discussions regarding learning styles, investigations into intelligence, and differentiation. But the sole purpose of this study was to begin a filtering process starting with traditional methods of vocabulary pedagogy versus a kinesthetic pedagogy. If the method proved worthy, then other studies could be made and subsequent variations of the study execution would be advised. Although it has been stated that there remains little research on the use of modeling clay in the

classroom, the curiosity and interest were present and a series of questions were developed and worked to form the basis of the study. The following three questions formed the basis of the study.

1. Is there a difference in vocabulary test scores between students who study biology vocabulary using modeling clay and those who do not use clay?
2. What are students' and teachers' perceptions regarding the use of modeling clay for biology vocabulary acquisition?
3. What are the challenges and benefits of using modeling clay for biology vocabulary acquisition in the classroom?

The first of the three research questions form the basis for the study with the data being answered by quantitative means. The second and third were qualitative in nature and thus a mixed method design was employed (Creswell, 2014).

Related Literature

The indecisiveness extant in direction for pedagogical methods in teaching vocabulary was a point of concern. If one wishes to build a home, for example, there are set procedures and guidelines to follow when installing a plumbing line or electricity. The vocabulary strategies toolbox (Georgia Department of Education, 2015) simply has a variety of methods for use in the classroom with no recommendations for use by class level, subject, or effectiveness. While it is true students need structure and a sound method to learn vocabulary (Behlol & Kaini, 2011), the state listing of methods includes, for the most part, engaging activities and graphic organizers. The NAEP statistics on vocabulary display a lack of adequate gains in vocabulary instruction since 2009 (U.S. Department of Education, 2013).

Furthermore, there are studies stating the need for specific targeting of vocabulary as a subject (Foil & Alber, 2002) and its mastery being vital in education. There are many proponents of vocabulary education, however, there are no offerings for the best way to learn or the most effective way to learn. Many researchers simply promote a variety of methods to be used (Ali et al., 2012; Foil & Alber, 2002; Naeimi & Foo, 2015; Nilforoushan, 2012).

Beyond classroom tools for teaching vocabulary, there are learning styles. Traditionally, there are visual, auditory, and kinesthetic approaches. Pritchard (2014) acknowledges the presence of all three styles in students. Yet, despite one student having more success with one style, he recommends the use of all. By using a student's less preferred learning style it could become stronger. Research from Sener and Cokcaliskan (2018) forwards the delineations of learning styles across six styles. In addition to visual, auditory, and kinesthetic, three more styles are included. Tactile, group and individual learning are now considered to be significant inclusions. The distinction made between tactile and kinesthetic is, respectively, in the use of hands versus the entire body. While Sener and Cokcaliskan (2018) use these two learning styles and in fact note that tactile is a preferred method, they also conduct inventories on Gardner's theory of multiple intelligences. Gardner (1983, 1993) does distinguish between tactile and kinesthetic. This study follows the lead set by Gardner and with the use of modeling clay in the study is considered to be kinesthetic in nature.

Current theories regarding the use of the brain and how words are learned included Paivio's DCT (Erfani, 2012: Moody et al., 2018). The outcomes from the study clearly indicated the value of engaging multiple sensory centers of students including

visual and kinesthetic. The use of clay activates kinesthetic learning as indicated by Gardner (1983). But the use of clay is also visual and activated a verbal channel to the brain. DCT clearly stated verbal and visual pathways in concert are more effective methods of producing results of understanding (Erfani, 2012). The direct use of DCT with science terminology has been successful and should be continued (Kortz et al., 2017; Rupley et al., 2015).

The incorporation of modeling clay for the study was decided upon as a result of my review of the research and the work of Dale (1947) and his theory of classroom instruction. Dale's cone of experience describes the engagement of students and outlines lessons based upon a scale from actual experiences to symbolic learning. A fundamental idea for Dale is that students learn better if they go through an experience. In other words, actually driving a car to learn how to drive is better than reading about it. The further students are removed from actual experience, the more difficult it is to learn. The furthest lessons from actual learning are symbols or language. Language is nothing but a series of symbols, such as letters, punctuation, numbers, and so forth. For the study, what Dale calls a contrived experience is created by having the students create items in clay. The method used in the classroom to form shapes and create definitions, as well as the method of verification by the teachers was taken from Hubbard (1996). This research provided the basis of the treatment classes. The methods describing how to form the clay so it creates a likeness, how to add labeling, and how to include an overall label were described. Once complete the teacher looked at the clay creation and was able to allow the student to move on or continue to work on the clay.

As a control class or group, the writing of sentences was used. Not only was this considered a more traditional method used in learning words but was the preferred method for learning words (Hubbard, 1996).

Methods

Based upon the three research questions the method needed to obtain answers was rather straightforward. The first research question was answered by assessments. The assessments were created for the study and used as pretests, posttests, and retention tests. The following two questions were added to provide depth and breadth to the study and formed the basis for a qualitative strand. Thus, the method design was an explanatory sequential mixed methods design (Creswell, 2014). The design, having provided answers to the first research question, stresses the quantitative strand. The secondary, or qualitative strand, supports the results and assists in explaining them (Creswell & Plano Clark, 2011). The whole purpose of the design was to discover, via a sequential explanatory study, the effectiveness of the use of modeling clay in high school biology vocabulary acquisition. The study involved the use of assessments from the two biology units. The first unit dealt with typical vocabulary concerning cells from Georgia standards. The second unit dealt with genetics terms. (See Appendices B and C for the word lists.) Assessments were given as pretests, posttests, and retention tests. The data from the assessments formed the majority of the quantitative data strand. After each unit student surveys were used to add to the quantitative data providing answers to the subsequent research questions. Finally, participating teacher interviews, consisting of ten questions, were conducted as qualitative data to fortify qualitative results and provide more insight regarding classroom operations and logistics.

Limitations

The limitations of the study could be considered to exist within a few particular domains. The primary limitation dealt with demographics. Concerns of generalizability may be pertinent about the study related to the quantity of student and teacher participants. Concerns of internal validity are also extant due to the number of participating teachers. The fact that the instruments were all created for the study are issues of internal validity. Finally, the uniqueness of the study does not allow for any comparison to previous research at the secondary education level.

The study was conducted in five classrooms in two public schools in southwest Georgia. The school populations fail to represent an average US demographic. The schools had a student population of approximately one thousand. While one school did have a Black population of 54% with a White population of 37%, the second school had a Black population of 78% with a White population of 14%. The gender division was virtually even. The demographics inspection also revealed both schools to be of a lower socio-economic status. Both schools were Title I schools.

The teachers who participated were both females. The teacher from the Spring of 2018, Teacher A, with two classes, possessed a M.A.T. degree with three years of biology teaching experience. The second teacher, Teacher B, oversaw three classes and possessed a Masters of Science degree and had fifteen years of experience in science with ten years in teaching biology. While the experience level does represent some variety, the fact that there were no male instructors or a higher number of instructors is limiting. These two teachers represented the entirety of the participants. Of the three other teachers who were initially willing, two were female and one was male. Their inclusion

would have assisted in the validity of the study. Initial plans did, however, include the ideal scenario for the study of having the participating teachers manage a Group S classroom as well as a Group C classroom. The interviews, because of the teachers conducting the study with both groups, provided better feedback and a broader input of considerations.

The study itself involved five classrooms varying in size from 12 to 24 students. Per IRB request the options to partake in the study as a member of Group C or Group S was met by having all classes divided into two halves. This enabled all students to participate in the study as both Group C and Group S members.

While the number of participants, n = 95, does constitute a decent database for a study, all the student participants are contained within a narrow demographic. The population, while not being representative of the country, was a fair representation of Georgia and its public schools.

The timing of the study in the different classrooms was a limitation. The first cells in the Spring of 2018 took approximately three months. All the other units took about one month to complete. Not only was there a difference in the time it took to complete a unit, but the speed with which the students finished their respective portions of the study varied. The tests were administered in a whole group setting, thus some students waited to take the posttest, retention test, or survey.

Although considered prior to commencing with such a study, the topic itself was limited to dealing with a statewide course in high school biology. This study does not branch out into any subject other than biology. While the use of science, specifically biology, and more specifically cells and genetics vocabulary terms may appear to limit

the study it does not. The intention was to use focused terminology not likely to be confused with other words or subjects previously studied. By doing so a sense of isolation was created enabling the data gathered to be more exacting. The only exception to this was the inclusion of the word nucleus which has other meanings in science, in particular, the center of an atom as opposed to

Use of peer review and subsequent adjustment enhanced confidence in the assessments used. The repetitive use of the assessments and consistency in results was also paramount in instrument assurance. Likewise, the surveys were repetitiously administered to Group C and Group S. And interviews were conducted with the same questions every time. There were over 520 assessments administered and graded; nearly 200 surveys administered and tabulated, and four teacher interviews conducted.

Assessment Results

The study was created to determine if using clay was a more effective pedagogical method for vocabulary than others. For this study Group C was conducted simultaneously with Group S. The test results from the study showed great improvement from the pretests to the posttests and from the pretests to the retention tests for every class.

The mean scores increased from the pretests anywhere from 14 points to over 18 points higher. The pretests taken in Group S were almost 3 percentage points higher than Group C classes. The posttests were also nearly 4 points higher for the Group S students than Group C. But with the retention tests, which were taken the week following the posttests, Group C scores did surpass those of Group S. Group C students did also have the highest gain with the retention test. Additionally, the *p* values for all the

comparisons with the pretests indicated a very significant statistical change ($p < .001$). This may simply be attributed to addressing vocabulary as a separate subject within biology, but the increase of Group C scores over those of Group S is not so easily dismissed. A closer look at gender, surveys, and interview feedback provide more compelling evidence for the benefits of using clay. Statistically, however, the comparisons between the control and treatment groups, respectively between Group S and Group C did not indicate any significance between each other. When analysis of the units took place it was noted that within the genetics unit the males and females both scored higher with Group C than with Group S.

Further analysis of data took place comparing results by gender. The point was to determine variance, if any existed, in the performance of males versus females. The data analysis revealed a similar gain in scores from the pretests to the posttests and pretests to the retention tests as the aggregate data. The percentage increase scores were noted as scoring from a low of 12.46 to 20.80. Group C males had a posttest increase from the pretest of 20.80 points and a retention increase of 19.14 points. Those in Group S only increased 18.52 points and 14.04 points, respectively. While the females in Group C went up 12.46 on the posttest, the retention test went up 16.30 and was the only group, male or female, to see an increase after the retention test. Analysis of Group C compared with Group S by unit, the genetics unit, which occurred after the cells unit, showed higher performance by Group C on the retention tests.

While the difference in mean scores showed variance between genders, the *t* tests did not show any significance and the *p* values in comparison were not of importance statistically. There were no other anomalies or data points justifying a further inspection.

The final result of the data analysis from the assessment instruments (pretest, posttest, and retention test), is the vocabulary pedagogical method of employing clay did not prove out versus the control group and its use of writing sentences.

The first research question was of primary concern and was answered by the assessments taken in Group C and Group S. Research question number one was stated as follows: Is there a difference in vocabulary test scores between students who study biology vocabulary using modeling clay and those who do not use clay? The null hypothesis would be: There is no significant difference in vocabulary test scores between those who study biology vocabulary using modeling clay and those who do not use clay. In this study Group C used clay and Group S did not use clay but wrote sentences. There was no statistical significance, but the effectiveness of using clay was demonstrated in the increase of posttest scores and retention test scores. The retention test gains were consistent in the genetics unit. Additionally, the use of clay was particularly effective with males by test scores and teacher comments.

These two gains will be further explored with continued analysis of the student surveys and the teacher interviews. The first area of note is the performance of students by gender. The second area requiring more analysis is the success of Group C as a kinesthetic methodology for learning vocabulary. Within the study, the writing of sentences as a traditional method of instruction was performed in contrast to the kinesthetic activity of clay model creation. The noteworthy achievement was the performance of Group C students remained on par with Group S.

Survey Results

The Group S surveys were comprised of twenty-five questions (see Appendix G). Group C surveys were composed of thirty questions (see Appendix F). Analysis of the surveys was conducted after the numeration of the questions occurred. The surveys were Likert-scale with strongly agree being a 1 and strongly disagree being a 5. The surveys contained questions pertaining to the second and third research questions. The second research question was: What are students' and teachers' perceptions regarding the use of modeling clay for biology vocabulary acquisition? The third research question was: What are the challenges and benefits of using modeling clay for biology vocabulary acquisition in the classroom?

The analysis of the survey questions focused on the mean scores. With the scale ranging from 1 to 5, the midpoint was 3. The first objective was to find outlier questions with either strong agreement or strong disagreement. Despite there being 25 questions on the Group S survey and 30 on the Group C survey there were few outliers present. The only question on the Group C survey above a 4 or below a 2 was Question 16 which dealt with student desire to stay late of after school to work on the clay. The response was $M = 4.10$. Thus, not many students were willing to remain. Similarly, from the Group S questions, Question 17 re sentences and remaining late had a $M = 3.67$ indicating disagreement. The other disagreement outlier indicated that spelling was not helped by the use of clay. There were five more outliers all were in agreement with the proposed survey question. The Group S outliers contained agreement with the following phrases: writing sentences was boring after a while; sentences helped me understand the words; writing the sentences helped me picture the meaning of the words. The Two

survey questions from Group C which were agreement outliers stated the clay was messy and that each new vocabulary word presented a new challenge.

Beyond inspection of the survey results for outliers, a comparison of mirror questions was conducted. The purpose was to discover differing views from Group S and Group C on the same topic. The first inspection was the similarity of mirror questions. Suppose a question on the Group C resulted in $M = 2.30$ and the topic was about using clay makes me feel sad. Then the question about writing sentences on the Group S survey had $M = 2.25$. The variance would be 0.05 and thus considered minimal. While looking at comparing statistics sometimes having no variance is important. The survey questions lacking variance between the two groups are considered within this section.

Question 2, which simply states that the students learned to appreciate the use of clay and the writing of sentences. While the students appreciated the various classroom activities, they also indicated they slightly agreed that they did not particularly like them as noted by Question 3 which also had a minimal variance of .04. This is a commentary upon either the design of the study or the appreciation of activities beyond the normal in their respective classrooms. Additionally, interviews brought to light the excitation concerning the newness of the use of clay followed by comments upon bored and loss of interest of the students in Group C. Both Group S and Group C felt the study methods should be used in other classes per Question 11.

There was no variance in agreement with Question 4. Both groups indicated they could picture the words better. This bolsters advocacy for learning styles, in particular, visual learning. Question 9 concerning the effectiveness of the use of clay or writing sentences was worded to require a negative response and thus the students disagreed that

the methods used did not help their understanding of the words. Question 23 was another question worded in the negative light stating the methods did not help clarify anything and was disagreed with by both Group C and Group S.

Question 7 did tie in with other comments about the length of the study. Students felt there was no need to continue with the clay or sentences after a few words. Question 13 indicates both Group C and Group S thought the use of clay and sentences took too much time. However, according to responses to Question 14 both groups also indicated the use of both methods became faster as they progressed. With Question 8 there was a variance with those in Group C disagreeing it was hard to work with the clay. However, for Question 8 those in Group S indicated a slight agreement that writing sentences was more difficult.

The final two questions, which exhibited little variance, were Questions 24 and 25 concerning spelling and pronunciation. Oddly enough both questions were slightly to the affirmative side of the scale. The questions were included in the surveys for Group C and Group S as a point of curiosity and to determine if the methods used were insidious regarding other aspects of language. Apparently this is the case as spelling and pronunciation were not part of clay manipulation and writing of sentences may assist with spelling, but certainly not the pronunciation of vocabulary terms. Paivio's DCT purports linguistic mastery along with visual input to the brain (Erfani, 2012). While methods from Group C and Group S have a visual aspect to them pronunciation and spelling are linguistic qualities not addressed.

Some survey questions resulted in a mean variance greater than .30. Those results are discussed as differing views among the two groups.

One trend visible in the responses between Group C and Group S is the higher interest level of those in Group C. Questions 6, 16, 17, and 21 all leaned towards wanting to do more with the clay or their hands. The variance of over 1 point between those wanting to work more with clay as opposed to writing sentences was impressive. Despite the Group C activities taking longer the Groups S students grew bored with the writing of sentences at a greater rate. Question 15 responses also attested to the preference for clay methodology as there was a neutral feeling (3.00) versus a disagreement with Group S for utilizing more words than were on the vocabulary list.

Group S responses rated higher for the effectiveness of sentence usage than students in Group C. Questions 1, 10, 12, and 18 dealt with methodologies helping to understand the words, picturing the words, providing more support than dictionaries, and memory, respectively. While the mirror question about memory had a variance of 0.73, this data does contradict the retention test results. Despite using clay in Group C it was interesting to note Group S students felt they could picture the words better.

There were three remaining questions with a mean variance of over 0.30. The first was Question 5 stating that the classroom methodologies were not necessary for understanding. Group C agreed slightly with the statement whereas Group S did not. Again, the assessment data seems to be in contraction to the survey data. Both Group C and Group S improved significantly over their pretest scores.

Question 19 also resulted in variance as Group S felt they could create sentences with any word and Group C disagreed with regards to the use of clay. The last question, Question 22, met with agreement from both groups, but Group S agreed more strongly that each word presented a new challenge.

The survey questions were all constructed to provide insights related to the effectiveness of the study methods, student perceptions concerning the study, challenges and benefits to the study, and motivation. The results outlined, while contradictory to the assessment results with two questions have provided valuable data concerning the study and the results. Most notably was the effectiveness of the study and Group S over Group C. These results are perceptions and the test results, especially those pertaining to gender, prove otherwise.

The challenges to the students, as well as the benefits, were not as significant as originally postulated. In fact, Group C students seemed to be more interested and willing than the reported interview responses.

Motivation, which relates to challenges and benefits, was an area where the surveys aligned with the feedback from interviews. There was no desire to comment on the work ethic, rigor, or levels of commitment regarding today's high school students, but a desire to master a subject may have been a point worthy of comment. Feedback regarding staying late, taking time, and persevering despite a lack of ease was disheartening.

Interview Results

The surveys conducted with the students provided information for the study from the viewpoint of the students who had either just completed a unit writing sentences or a unit creating clay representations of the words. The interviews conducted provided an opportunity to gather input from the teachers involved in the study. The objective of the interviews was to answer in part the second and third research questions. The second research question was: What are students' and teachers' perceptions regarding the use of

modeling clay for biology vocabulary acquisition? The third research question was: What are the challenges and benefits of using modeling clay for biology vocabulary acquisition in the classroom?

Both teachers were veterans in science education and responded succinctly to the interview question. The ten questions were designed to solicit data in response to research questions two and three. The interviews, totaling four, took place with each teacher after the unit on cells and after the unit on genetics. The science teachers conducted themselves in a professional manner and promptly responded to the interview questions. However, despite additional prompts, the responses remained brief. A few responses were recorded as a single sentence or phrase. The information provided was very useful, albeit concise, as may be expected from science instructors.

Upon completion of the interviews, the responses were culled through and four themes were identified. For comments to be considered themes worthy of note in the study required two elements. The first element was the repetition of similar comments at least twice. The second element was similar comments mentioned by both teachers. The reason behind the need for such qualification was the limited number of teachers used in the study. If two separate teachers from two portions of the study conducted at different times made similar comments, more internal validity existed. These dual utterances and repetition were considered saturation of the subject and worthy of comment.

In fact, the themes repeated were not only mentioned more than four times, but they were also the only ones mentioned by both teachers. The themes were both positive and negative regarding the execution and effectiveness of the study. One negative series of comments dealt with the difficulty in working with the clay and its hardness in

manipulation. The second negative group of comments concerned boredom and the use of clay took too much work. There were positive comments made along the line of excitation and novelty in using clay. The last theme was also positive and weighed heavily upon the findings. The final theme was engagement and focus on the clay itself. Beyond the brevity of feedback from the participating teachers, another point worthy of note is the variance in the conversation between Teacher A and Teacher B. Teacher A is noted as having discussed the four themes 9 times while Teacher B had comments to make about the theme 17 times. It should also be noted that Teacher B had more than four times the teaching experience than Teacher A. The included themes were mentioned a total of either six or eight times by the teachers during the interviews. Any other comments were not repeated by either the same teacher in subsequent interviews or by the other teacher at all.

The first theme listed pertained to a challenge in the study. The theme was also a negative aspect and related to the hardness of the clay itself and difficulty in manipulation. Teacher A shared comments on the difficulty twice while Teacher B discussed this concern four times. The fact is modeling clay, which was commented upon as having the quality of not drying out, can be rather difficult to massage into various forms initially. Once the clay was warmed-up it was fine to work with to form the desired shapes. Students had to cut the clay with rulers, scissors, or use rollers for it to be more manageable. This did create some hindrances as noted by the teachers.

A natural segue to the first theme is the negative aspect of the teachers reporting the study took too much work and left the students bored. This was brought up at three different times in the interviews by both teachers. The clay being difficult to manage and

manipulate may have led to the comments upon this strand and given it more credence. According to the data from the interviews with the teachers, the hardness of the clay was mentioned six times and the students becoming bored or thinking the work was too much was mentioned seven times.

The two positive repeating comments were also related to each other to some degree. The first theme, mentioned six times, was the newness of the activity and how it generated a sense of excitement or novelty. The use of clay was not employed by either participating teachers previously. The issues of discipline and classroom management were negligible per the interviews. In fact, the use of direct vocabulary instruction, as opposed to using the biology terms in context and as they are included within a unit of instruction, was new as well in all five classrooms. Thus, beyond the direct vocabulary pedagogy, the inclusion of clay was a new concept to the teachers and students. The effectiveness of direct use of vocabulary instruction has been noted by various researchers including Marzano (2010).

The final theme, and second positive theme was the mention of engagement and level of focus for the students participating with clay. During the ten questions from the interview responses of this nature were noted eight times. Students working intensely with the clay was viewed positively. While some comments were made about keeping students on task (due to either playing a bit or making things they were not supposed to make) the students were actively working with clay. This included a statement by Teacher B regarding students who may not have been as scholastic as others were more engaged with the clay. A pertinent finding, which correlates with other data is that the male students were more prone to become involved with the clay.

The four repeated themes dealt with clay and Group C. The third research question addresses specifically the use of clay in the classroom. The interview feedback provides two challenges and two benefits. The students and teachers discovered the clay can be hard to work with and the work can be tedious or boring. Note the survey data did not stress the aspects of boredom as much as the teacher feedback. Benefits included the novelty or excitation for Group C, which was also noted in the surveys. The other benefit noted by teachers was the engagement.

Other issues, such as planning, classroom logistics, cleaning, and the like were not items of concern. The answers provided via student surveys effectively provided feedback to the second research question. The interview data did not produce additional substantial commentary regarding perceptions on Group C methods. The teachers simply conducted the study as requested. Beyond the room set up and the inclusion in their lesson plans, there were no other accommodations provided.

Combined Data

In considering the sum of all the data from the assessments, surveys, and the interviews, the purpose of gathering data in a multiple source fashion was to provide supplemental information regarding the first research question. The explanatory sequential design lends itself to having qualitative data, which comes later, bolster the quantitative data results. The first research question queries the difference between the use of clay in vocabulary pedagogy and other methods. In this study, the promoted alternative method for Group S was sentence writing. Students could also have used flash cards, memorization, or any other method desired without manipulatives. In the end, however, the students in Group S chose to only write sentences. Both groups were

free to use their textbooks, glossaries, or dictionaries. Regardless of the class or group, the surveys and the teacher interviews provided more data about the study and its execution to comment upon the value of using clay in the classroom for vocabulary acquisition. The surveys and interviews were designed to obtain data about the perceptions, challenges, and benefits of using clay as a classroom tool. Although the quantitative data did not prove to support the position of clay being a successful method of vocabulary acquisition in the classroom the use and analysis of clay in the classroom did result in some noteworthy findings.

The first item of note is the use of manipulatives. The clay used was a more interactive manipulative by its nature than a die or block in a math class due to the fact of one having to shape the pieces rather than simply change position. The use of manipulatives in vocabulary is not new and recommended by Dunn and Dunn (2005) and Beck et al. (2013). Given the evidence to hand, the jump in mean test scores from the pretests to the subsequent posttests and retention tests supports the literature

Additionally, the efforts have failed to not merely find another method, but the best methods of vocabulary pedagogy, reinforce the previously discussed approaches recommended by authors and researchers in the field of vocabulary pedagogy. It was noted that recommendations of the use of multiple techniques lacked any substantial promotion for said techniques. Furthermore, no pedagogical methodology was offered with results of effectiveness. In particular, authors simply promote a number of tools to use to learn vocabulary (Blanchowicz & Fisher, 2012; Dale, 1947; Pritchard, 2014). This study has provided another method, which remains as effective as using words in sentences to learn science vocabulary.

Specific input from the qualitative data does not exist per se. However, the increases in the test scores from the pretests can potentially be linked to the survey results noting that sentences helped students picture the words more clearly, the writing of sentences helped the students understand the words, and every word encountered when using clay presented a new challenge. This finding aligned with interview data which stated the clay was engaging, students were focused, excited, and the clay represented a novelty.

There was a positive result noted in both the quantitative data and the qualitative feedback as regards gender. Although the *t* tests did not result with a *p* value indicating statistical significance leading to the ability to claim the null hypothesis of the superiority of the use of clay in vocabulary pedagogy the mean scores for the males using clay were a few percentage points higher as previously stated. The interviews conducted with Teacher B from the Fall of 2018 noted that the males were both more engaged and seemed to be more involved with the clay in the study.

Although possibly contrary, the teachers mentioned the students grew bored and tired with the clay from the interviews and the surveys stated the clay was messy, and the students had little desire to remain late or work after school. Students writing sentences also had little desire to stay late or work after school. This, coupled with the noted procedural comment of the students only writing the three sentences, seems to point out that students of today will do the minimum of what was asked or required.

Recommendations for Future Research

The quantitative results did not show a great deal of positive outlook for the use of clay representations as the best method in vocabulary pedagogy. The most promising

aspect of the results in the study is verification of what Marzano (2010) stated regarding the value in teaching vocabulary as a separate subject. Due to the increase in test scores from the pretests, there is clearly value in the use of clay. The methodologies employing sentences and clay produced nearly equivalent results. As such, any future study would be justified in adding clay to the list of pedagogical options. The results also paired kinesthetic methodology against a more traditional method of using vocabulary words in sentences. Although the clay was not seen as a novel approach to vocabulary acquisition by outscoring other methods the use of clay may be as effective as other methods and employed in future studies with similar results.

Another discovery showing possible future study potential deals with the gender of the participants. Any investigation into the use of clay in the future would do well to include analysis of male attitude and perception in participation and observed engagement. Further investigation into the more effective or preferred methodologies of vocabulary pedagogy would do well to consider gender and manipulatives. This is validated by the research of Ramerzani et al. (2015) who found that males preferred learning by kinesthetic means. The study also showed that females preferred auditory learning. Sener and Cokcaliskan (2018) found, in younger students that tactile learning and auditory learning were preferred. Thus, the use of manipulatives, including the use of clay, could be considered a valid option in the future.

The study itself was contained within the state of Georgia. Future studies may be used to expand across the Southeast or the United States. Additional studies in Southern states such as Alabama, Mississippi, and the Carolinas may also provide valuable comparative data. Desires to branch out to other demographics could also be done

locally by selecting schools that are not Title 1. Areas with more dense populations such as Columbus or Atlanta have a larger number of private schools possibly providing more future study options.

As with the reasoning behind selecting biology in this study, DCT studies have involved science vocabulary as well (Kortz et al., 2017; Rupley et al., 2015). The use of science vocabulary in this study was an effort to counter the polysemic nature of the English language. Regardless of potential linguistic pitfalls, future studies could include other subjects. Expansion for the effectiveness may go beyond adding other sciences such as chemistry or physics. Beyond the realm of science, teacher interviews suggested general concepts in English as well as scenes from poems or novels. Similarly, a suggestion was offered to create scenes from written works or possibly battle scenes from history classes. This study was created with the purpose of discovering the best possible means of vocabulary acquisition. Future implementation of the use of clay may simply be to effect a varied approach or a clearer approach to understanding terminology in different fields.

Studies in the future would be best framed concerning the grade level, gender, and learning styles. This study was concerned with high school students and used a traditional method of pedagogy in Group S in contrast to a non-traditional method with modeling clay in Group C. The actual application was a visual learning style of writing sentences compared to a kinesthetic or tactile method of learning. Another possible study design might include auditory lessons versus modeling clay. Within such a study, variances in results could be evaluated to narrow any possible causes such as gender, grade level, and results compared with learning styles or applications of DCT.

Kinesthetic study designs could also be done to have clay models versus manipulatives, skits, dance, or other more bodily oriented learning styles. One important consideration for the study was the application of kinesthetic as defined by Gardner (1983). The fact that Gardner does not make a distinction between the use of the hands playing the piano and the running of an individual down the street may be of significance in future studies. The reasoning is the increased use of video game controllers and computers which could be perceived as kinesthetic. The inspection of study results based upon gender may prove valuable.

Any number of studies could be designed and conducted for a number of grade levels as well. Thus, the preferences for vocabulary pedagogy could be determined for elementary girls or elementary boys. The best vocabulary pedagogy could be continued for middle school boys and then high school students as well. The intent of such a series would be the determination of the best methods to teach students vocabulary based upon grade level and gender.

Cited works have included the use of clay in vocabulary acquisition at the elementary and collegiate levels (Chumark & Puncrebutr, 2016; House, 2007; Kooloos et al., 2014). This study, conducted at the high school level, is unique. Thus, investigations into the use of clay at the high school level remain untested and a frontier worthy of further testing.

Although a limited scope of terminology was used for the study, using the procedures outlined within this study, the expansion into other studies remains open-ended. Investigation beyond additional disciplines may also include changes to the assessment tools, methods of student participation, data acquisition, and the interview

process. A longer study may consider the use of focus groups and having students use clay in various disciplines in sequence or in concert. The options are as varied as any researcher desires to make them. As long as the ultimate purpose, vocabulary acquisition, remains intact, the variations would be justified. The use of clay in vocabulary pedagogy may yet be determined to be engaging, useful, and extremely effective.

One of the primary concerns stated at the outset of the study was the lack of any type of grading or ranking system with the Georgia Department of Education (2015) has a vocabulary strategies toolbox. At the very least future studies should be geared to determine a system of evaluation for methods of vocabulary instruction. The system may have to include such qualifiers as grade level and gender. For example, if the Georgia Department of Education toolbox included a teaching method and a statement such as "Research has shown this instructional practice works well with middle school girls," or the like it would be very helpful for educators when creating lesson plans. While such a grading or rating system for vocabulary instruction may not be universal or accepted by most educators, the inclusion of input would possibly be of value to some.

To date, no one has discovered a perfect, or best, method to learn vocabulary. This study attempted to add the use of clay as a better method for students to obtain an understanding of vocabulary words. The goal was not obtained, but a new method was added to learning vocabulary. Future studies should include manipulatives, and, if possible, include the use of clay as described herein.

Conclusions

This vocabulary study was effective and produced five valuable results. The first result was the use of kinesthetic learning was as effective or better than traditional methods of vocabulary acquisition. The increase of test scores from pretest to posttest and retention test in Group C, using clay, was on par with the use of sentence writing. Males scored better on the retention tests and within the genetics retention test analysis both males and females scored higher in Group C than in Group S. Data from Table 1, Table 8, and Table 9, as well as Figure 6, all indicated clay was a successful classroom tool. The success was marked by retention test results which exceeded the results from Group S. Not only was clay an effective tool in the classroom but using clay was akin to approximating an experience with microscopic entities in the classroom in alignment with multisensory practices such as DCT. Per the test results and teacher interviews, males were able to perform better with the use of clay. This was discovered in Group C with posttest and retention test data. The last finding from the study was the validation of information from Marzano (2010) who stated that vocabulary should be addressed as a separate subject.

While an argument may be made stating the study did not result in finding the most effective way to learn vocabulary, kinesthetic learning was found to perform as well as more traditional methods of vocabulary acquisition. Dale (1947) coined the term contrived experience to mean an event taking place in the classroom simulating an experience. While there exist many actionable lessons, many are limited due to the physical world. For example, here in Georgia a class may easily step outside and understand farming, whereas looking at an atom is not as readily accomplished. Through

the execution of the study, students were able to create, with clay, components of cells and concepts in genetics they might never have attempted or conceived of before. Whether one refers to the use of clay as kinesthetic or tactile a contrived experience is taking place (Dale, 1947). With Group C the teacher planned for an experience which the students then took part in. The students actually created, with clay, a cell, a nucleus, a recessive gene. They experienced vocabulary words with their hands. This was not as enriching as learning about planting seeds by going outside, but some subjects are far more unreachable physically than others.

The use of clay in Group C was able to produce results similar to the use of sentences in Group S which was a more traditional and scholastic avenue. The results also indicate that males prefer hands-on activities. The results of the study also indicate the introduction of variety and novelty in learning proved as valuable as the simple exercise of writing sentences. The Group C classroom method was artistic. There was no question that the use of clay took more time than the writing of sentences in Group S. However, the gains were seen within the retention test analysis and the continued use of clay in the second unit justify its use in the classroom. There were no comments made by teachers about the students taking the time to make their clay creations works of art. But the use of clay was new for all the students and for both teachers. The males were more engaged. And the gender test results are worthy of future studies. Students working and enjoying their learning methodology is never anything to ignore.

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APPENDIX A:

Checklist for Biology Cells Unit

Cells Checklist

School number: _____ Student number: _____

Starting date: _____ Completion date: _____

___ Pretest administered

___ Active Transport
___ Cell membrane
___ Cell wall
___ Chloroplast
___ Diffusion
___ Endocytosis
___ Exocytosis
___ Eukaryote cell
___ Hypertonic
___ Hypotonic
___ Lipid bilayer
___ Nucleus
___ Organ system
___ Organelle
___ Osmosis
___ Passive transport
___ Prokaryote cell
___ Protein channel
___ Rough endoplasmic reticulum
___ Selective permeability

___ Posttest administered
___ Retention Test administered
___ Student Survey administered

APPENDIX B:

Checklist for Biology Genetics Unit

Genetics Checklist

School number: _____ Student number: _____

Starting date: _____ Completion date: _____

___ Pretest administered

___ Allele
___ Anaphase
___ Chromosome
___ Crossing over
___ Cytokinesis
___ Diploid cell
___ Dominant trait
___ DNA
___ Gene
___ Haploid cell
___ Heterogeneous
___ Homozygous
___ Meiosis
___ Mitosis
___ Phenotype
___ Prophase
___ Punnett square
___ Recessive trait
___ Transcription
___ Translation

___ Posttest administered
___ Retention Test administered
___ Student Survey administered

APPENDIX C:

IRB Parental Permission Form

VALDOSTA STATE UNIVERSITY

Consent to Participate in Research

You are being asked to participate in a research project entitled "An Explanatory Sequential Mixed Methods Investigation into High School Biology Vocabulary Acquisition." This research project is being conducted by Robert Bailey, a student in *Curriculum and Instruction* at Valdosta State University. The researcher has explained to you in detail the purpose of the project, the procedures to be used, and the potential benefits and possible risks of participation. You may ask the researcher any questions you have to help you understand this project and your possible participation in it. A basic explanation of the research is given below. Please read this carefully and discuss with the researcher any questions you may have. The University asks that you give your signed agreement if you wish to participate in this research project.

Purpose of the Research: This study involves research. The purpose of the study is to evaluate whether using modeling clay is a better method of learning biology vocabulary than more traditional methods of learning words such as writing sentences, using flashcards, or graphic organizers.

Procedures: You will participate in several activities. The first activity you will be involved with is orientation and training. The training will take place at your school, in your classroom. An overview of the study will be outlined and discussed. The outline will state that you are a volunteer and teacher in either an experimental classroom, a control classroom, or both. The classrooms are where all activities with students will take place.

You will administer a pretest on vocabulary, the same test as a posttest, and then the week following the posttest you will administer a retention test. You will not grade any test. You will only ensure every participating student receives a test and completes the test. The researcher will grade all materials.

You will also distribute surveys and upon completion, collect them. You will not analyze or score the surveys.

In the experimental portion of the study, you will be provided all materials to allow your students to create clay representations of vocabulary words and phrases from the cells unit and genetics unit in biology class. You will set out clay, tools, paper, file folders, scissors, and wipes for cleaning. You will have checklists of the words students must represent in clay. You will also inform students if their creation is passing or if more work is needed. Your orientation and training will instruct you on how to judge clay creations.

In the control portion of the study you will allow ample time for students to review and learn the same vocabulary words. You will also ensure each student writes at least one sentence using the vocabulary word in a manner indicating the student understands the meaning of the word. You will participate in two interviews with the researcher which will be recorded. One interview will take place after the students complete the unit on cells and one after the unit on genetics. The interviews will be recorded and maintained by the researcher until they are transcribed. Once transcribed the recordings will be deleted. The transcriptions will be maintained with no names or locations and destroyed after three years when there will be no need for review or critique of study data. This is the identical timeframe as all other data from the study which will likewise be destroyed by shredding.

The units will be supplemental to your regular curriculum and should not add more than a week to each unit. The activities involved in the study cover information germane to the high school biology curriculum and serve to enhance the students' learning. You may be asked by students to supervise them before, during, or after school in order to facilitate completion. You may also have to arrange multiple workstations to boost completion rates. Your own judgement will be needed and exercised in such requests and actions.

You will be asked to maintain checklists of each unit for every student. You will be requested to remove any names or identifiers from all checklists before surrendering them to the researcher upon completion of the unit. You will also be requested to maintain a diary or take notes during the duration of the study and voice issues or concerns with the researcher during the interviews.

You will be provided with the name, phone number, and email of the researcher for contact at any time during or after the study. Your input is considered valuable and will be expected. Beyond participating in the experimental classroom or the control classroom there are no other alternatives. The only other alternative is to choose not to participate at all.

Possible Risks or Discomfort: You and your students will be working with hypoallergenic modeling clay. Working with clay, especially if it is cold, can be difficult. You and your students may become frustrated with the clay until it is warmed up. You may not be very good at creating clay representations of the words. You may refer to your training or contact the researcher if you have any questions. The maintenance of your room, including clean up, is your own province. Although there are no known risks associated with these research procedures, it is not always possible to identify all potential risks of participating in a research study. However, the University has taken reasonable safeguards to minimize potential but unknown risks.

All tests, surveys, checklists, clay, paper, file folders, wipes, etc. will be provided free of charge. There are no costs associated with the study. If it is discovered, during the course of the study, that any item(s) are lacking they will be delivered to you.

By agreeing to participate in this research project, you are not waiving any rights that you may have against Valdosta State University for injury resulting from negligence of the University or its researchers.

Potential Benefits: Possible benefits gained from your participation in the study include greater awareness of the use of kinesthetic activities, increased focus on vocabulary as a subject, and understanding the use of clay as a teaching tool. Although you may not benefit directly from this research, your participation will help the researcher gain additional understanding of vocabulary pedagogy.

Costs and Compensation: As all materials will be provided to you there are no costs to you for participation in the study. You will be required to remain for interviews, at your school, after each unit is completed. Also, if your students ask you to stay late or come in early to supervise their study activities, that will be additional time. Although there is no compensation for taking part in the study, a drawing will be held to award two participating teachers with a $50.00 gift card to Amazon.

Assurance of Confidentiality: Valdosta State University and the researcher will keep your information confidential to the extent allowed by law. Members of the Institutional Review Board (IRB), a university committee charged with reviewing research to ensure the rights and welfare of research participants, may be given access to your confidential information.

No tests and surveys will contain names or identifiers. All information gathered by the researcher will be noted as experimental group or control group. Participating schools will be given a numeric identifier and you will be noted as the teacher for the experimental classroom, the control classroom, or both. Your name will not be included on any records kept. You will be asked to complete demographic data including gender, race, years of teaching experience, and education level, but your name will not be linked to the data at all. Any retrieved paperwork from the class must stricken of names, locations, or other identifiers. All tests will be scored by the researcher. All survey results will be recorded by the researcher. Hard copies of the tests and surveys will be maintained by the researcher and filed by classroom and stored for three years. After three years the files will be shredded.

All data gathered from you or your students will be included in the classroom data, gender data as an aggregate, race data as an aggregate, school data as an aggregate, and for comparisons between schools as an aggregate. The data will be included in the researcher's findings as previously described and published as such. At no time will data be presented with the classroom teacher's name or school name. School system names may be used, but they will not be connected to any numbering information. Every reasonable precaution will be used by the researcher to maintain anonymity.

Voluntary Participation: Your decision to participate in this research project is entirely voluntary. If you agree now to participate and change your mind later, you are free to leave the study. Your decision not to participate at all or to stop participating at any time in the future will not have any effect on any rights you have or any services you are otherwise entitled to from Valdosta State University.

Participation in the study includes training, test administration, survey administration, overseeing production of your students in the experiment, maintaining checklists and notes, and partaking in interviews. You may skip any questions that you do not want to answer.

Information Contacts: Questions regarding the purpose or procedures of the research should be directed to Robert Bailey at (229)942-6820 or rjbailey@valdosta.edu. This study has been approved by the Valdosta State University Institutional Review Board (IRB) for the Protection of Human Research Participants. The IRB, a university committee established by Federal law, is responsible for protecting the rights and welfare of research participants. If you have concerns or questions about your rights as a research participant, you may contact the IRB Administrator at 229-333-7837 or irb@valdosta.edu.

Agreement to Participate: The research project and my role in it have been explained to me, and my questions have been answered to my satisfaction. I agree to participate in this study. By signing this form, I am indicating that I am 18 years of age or older. I have received a copy of this consent form.

I would like to receive a copy of the results of this study: _____ Yes _____ No

Mailing Address: _____

e-mail Address: _____

_____

Printed Name of Participant

_____

Signature of Participant Date

_____

Signature of Person Obtaining Consent Date

This research project has been approved by the Valdosta State University Institutional Review Boa for the Protection of Human Research Participants through the date noted below:

APPENDIX D:

IRB Teacher Consent Form

VALDOSTA STATE UNIVERSITY

Consent to Participate in Research

You are being asked to participate in a research project entitled "An Explanatory Sequential Mixed Methods Investigation into High School Biology Vocabulary Acquisition." This research project is being conducted by Robert Bailey, a student in *Curriculum and Instruction* at Valdosta State University. The researcher has explained to you in detail the purpose of the project, the procedures to be used, and the potential benefits and possible risks of participation. You may ask the researcher any questions you have to help you understand this project and your possible participation in it. A basic explanation of the research is given below. Please read this carefully and discuss with the researcher any questions you may have. The University asks that you give your signed agreement if you wish to participate in this research project.

Purpose of the Research: This study involves research. The purpose of the study is to evaluate whether using modeling clay is a better method of learning biology vocabulary than more traditional methods of learning words such as writing sentences, using flashcards, or graphic organizers.

Procedures: You will participate in several activities. The first activity you will be involved with is orientation and training. The training will take place at your school, in your classroom. An overview of the study will be outlined and discussed. The outline will state that you are a volunteer and teacher in either an experimental classroom, a control classroom, or both. The classrooms are where all activities with students will take place.

You will administer a pretest on vocabulary, the same test as a posttest, and then the week following the posttest you will administer a retention test. You will not grade any test. You will only ensure every participating student receives a test and completes the test. The researcher will grade all materials.

You will also distribute surveys and upon completion, collect them. You will not analyze or score the surveys.

In the experimental portion of the study, you will be provided all materials to allow your students to create clay representations of vocabulary words and phrases from the cells unit and genetics unit in biology class. You will set out clay, tools, paper, file folders, scissors, and wipes for cleaning. You will have checklists of the words students must represent in clay. You will also inform students if their creation is passing or if more work is needed. Your orientation and training will instruct you on how to judge clay creations.

In the control portion of the study you will allow ample time for students to review and learn the same vocabulary words. You will also ensure each student writes at least one sentence using the vocabulary word in a manner indicating the student understands the meaning of the word. You will participate in two interviews with the researcher which will be recorded. One interview will take place after the students complete the unit on cells and one after the unit on genetics. The interviews will be recorded and maintained by the researcher until they are transcribed. Once transcribed the recordings will be deleted. The transcriptions will be maintained with no names or locations and destroyed after three years when there will be no need for review or critique of study data. This is the identical timeframe as all other data from the study which will likewise be destroyed by shredding.

The units will be supplemental to your regular curriculum and should not add more than a week to each unit. The activities involved in the study cover information germane to the high school biology curriculum and serve to enhance the students' learning. You may be asked by students to supervise them before, during, or after school in order to facilitate completion. You may also have to arrange multiple workstations to boost completion rates. Your own judgement will be needed and exercised in such requests and actions.

You will be asked to maintain checklists of each unit for every student. You will be requested to remove any names or identifiers from all checklists before surrendering them to the researcher upon completion of the unit. You will also be requested to maintain a diary or take notes during the duration of the study and voice issues or concerns with the researcher during the interviews.

You will be provided with the name, phone number, and email of the researcher for contact at any time during or after the study. Your input is considered valuable and will be expected. Beyond participating in the experimental classroom or the control classroom there are no other alternatives. The only other alternative is to choose not to participate at all.

Possible Risks or Discomfort: You and your students will be working with hypoallergenic modeling clay. Working with clay, especially if it is cold, can be difficult. You and your students may become frustrated with the clay until it is warmed up. You may not be very good at creating clay representations of the words. You may refer to your training or contact the researcher if you have any questions. The maintenance of your room, including clean up, is your own province. Although there are no known risks associated with these research procedures, it is not always possible to identify all potential risks of participating in a research study. However, the University has taken reasonable safeguards to minimize potential but unknown risks.

All tests, surveys, checklists, clay, paper, file folders, wipes, etc. will be provided free of charge. There are no costs associated with the study. If it is discovered, during the course of the study, that any item(s) are lacking they will be delivered to you.

By agreeing to participate in this research project, you are not waiving any rights that you may have against Valdosta State University for injury resulting from negligence of the University or its researchers.

Potential Benefits: Possible benefits gained from your participation in the study include greater awareness of the use of kinesthetic activities, increased focus on vocabulary as a subject, and understanding the use of clay as a teaching tool. Although you may not benefit directly from this research, your participation will help the researcher gain additional understanding of vocabulary pedagogy.

Costs and Compensation: As all materials will be provided to you there are no costs to you for participation in the study. You will be required to remain for interviews, at your school, after each unit is completed. Also, if your students ask you to stay late or come in early to supervise their study activities, that will be additional time. Although there is no compensation for taking part in the study, a drawing will be held to award two participating teachers with a $50.00 gift card to Amazon.

Assurance of Confidentiality: Valdosta State University and the researcher will keep your information confidential to the extent allowed by law. Members of the Institutional Review Board (IRB), a university committee charged with reviewing research to ensure the rights and welfare of research participants, may be given access to your confidential information.

No tests and surveys will contain names or identifiers. All information gathered by the researcher will be noted as experimental group or control group. Participating schools will be given a numeric identifier and you will be noted as the teacher for the experimental classroom, the control classroom, or both. Your name will not be included on any records kept. You will be asked to complete demographic data including gender, race, years of teaching experience, and education level, but your name will not be linked to the data at all. Any retrieved paperwork from the class must stricken of names, locations, or other identifiers. All tests will be scored by the researcher. All survey results will be recorded by the researcher. Hard copies of the tests and surveys will be maintained by the researcher and filed by classroom and stored for three years. After three years the files will be shredded.

All data gathered from you or your students will be included in the classroom data, gender data as an aggregate, race data as an aggregate, school data as an aggregate, and for comparisons between schools as an aggregate. The data will be included in the researcher's findings as previously described and published as such. At no time will data be presented with the classroom teacher's name or school name. School system names may be used, but they will not be connected to any numbering information. Every reasonable precaution will be used by the researcher to maintain anonymity.

Voluntary Participation: Your decision to participate in this research project is entirely voluntary. If you agree now to participate and change your mind later, you are free to leave the study. Your decision not to participate at all or to stop participating at any time in the future will not have any effect on any rights you have or any services you are otherwise entitled to from Valdosta State University.

Participation in the study includes training, test administration, survey administration, overseeing production of your students in the experiment, maintaining checklists and notes, and partaking in interviews. You may skip any questions that you do not want to answer.

Information Contacts: Questions regarding the purpose or procedures of the research should be directed to Robert Bailey at (229)942-6820 or rjbailey@valdosta.edu. This study has been approved by the Valdosta State University Institutional Review Board (IRB) for the Protection of Human Research Participants. The IRB, a university committee established by Federal law, is responsible for protecting the rights and welfare of research participants. If you have concerns or questions about your rights as a research participant, you may contact the IRB Administrator at 229-333-7837 or irb@valdosta.edu.

Agreement to Participate: The research project and my role in it have been explained to me, and my questions have been answered to my satisfaction. I agree to participate in this study. By signing this form, I am indicating that I am 18 years of age or older. I have received a copy of this consent form.

I would like to receive a copy of the results of this study: _____ Yes _____ No

Mailing Address: _____

e-mail Address: _____

_____

Printed Name of Participant

This research project has been approved by the Valdosta State University Institutional Review Boa for the Protection of Human Research Participants through the date noted below:

_____

Signature of Participant Date

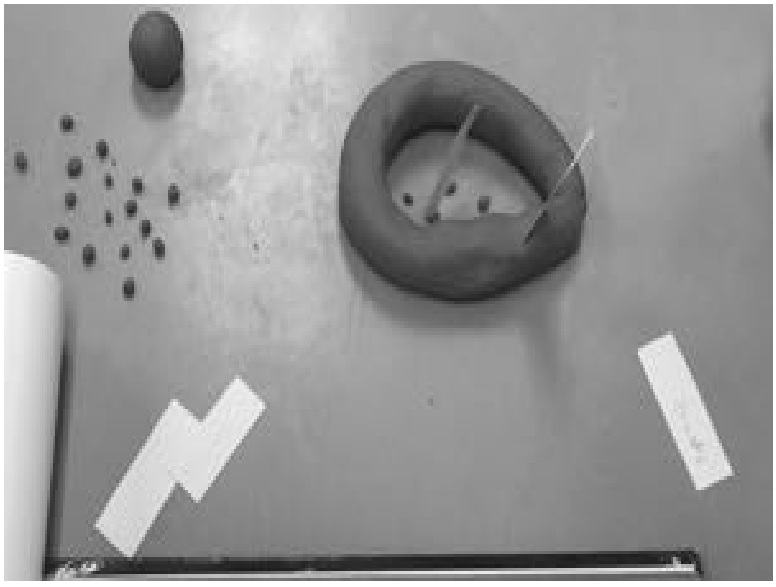
_____

Signature of Person Obtaining Consent Date

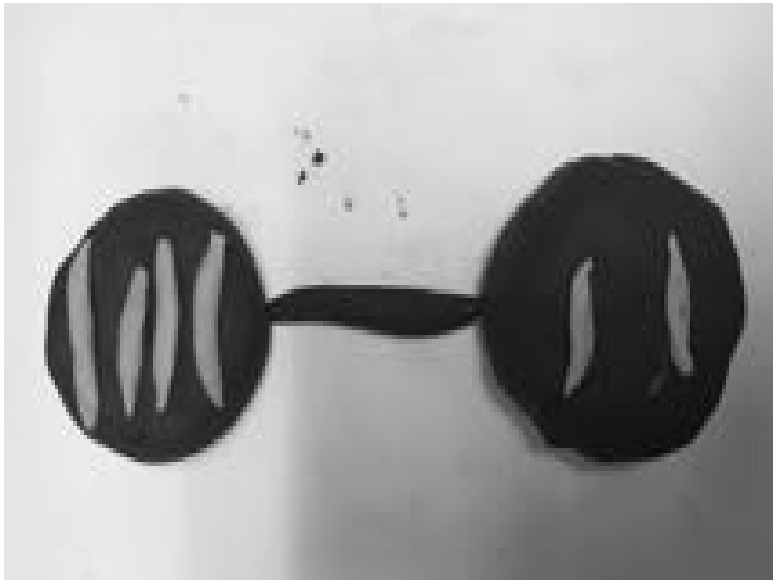
APPENDIX E:

Photographs of Student Work

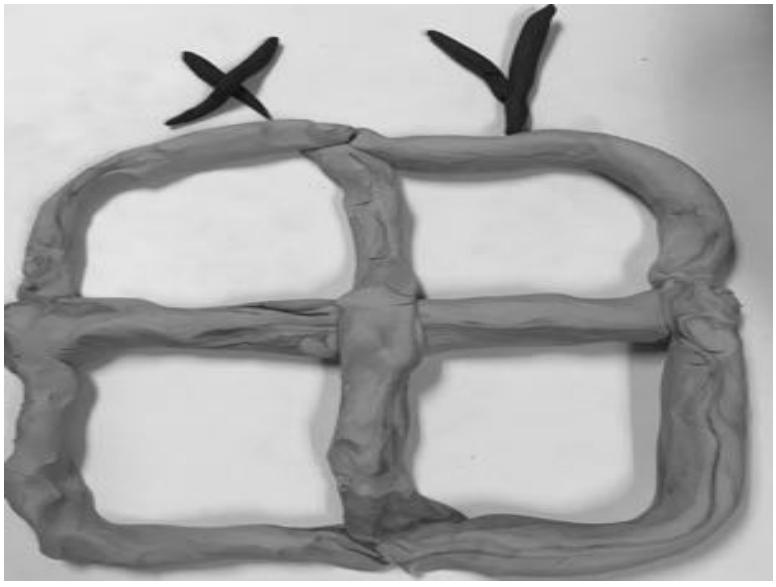
(Example of student work including clay, rolling pin, and vocabulary checklist)



(Example of student work including clay and labels)



(Example of genetics word in clay)

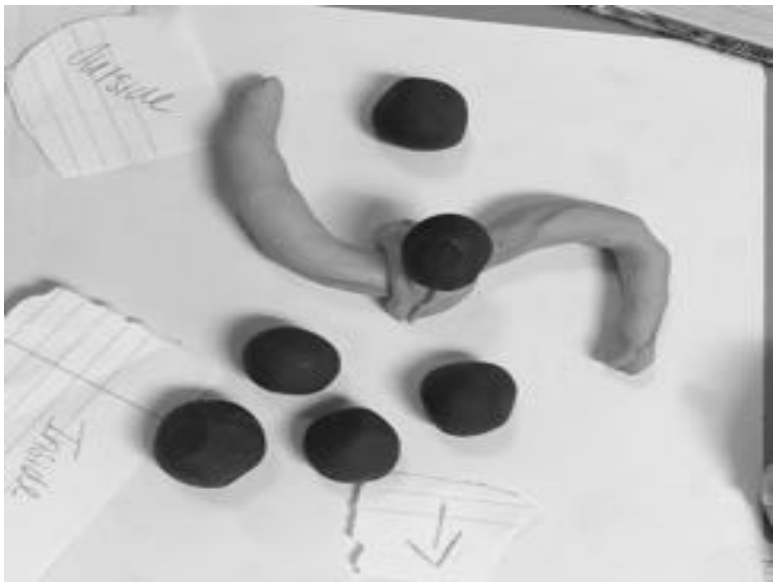


(Punnett square done in clay from the genetics unit)

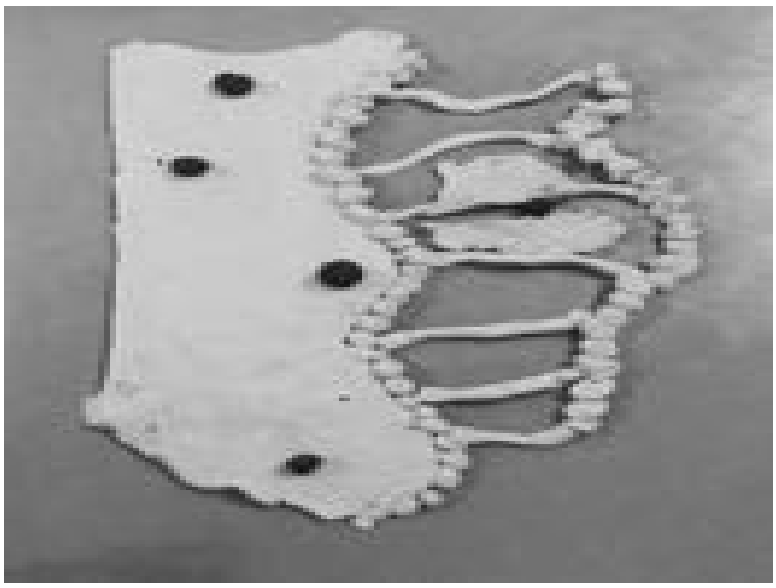
(Crossing over term from genetics unit done in clay)

(Genetics term done in clay)

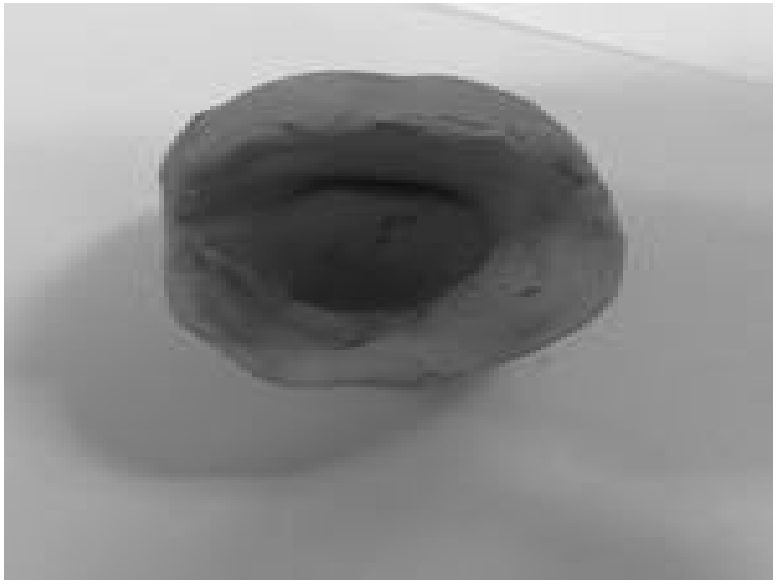
(Cell done in clay)



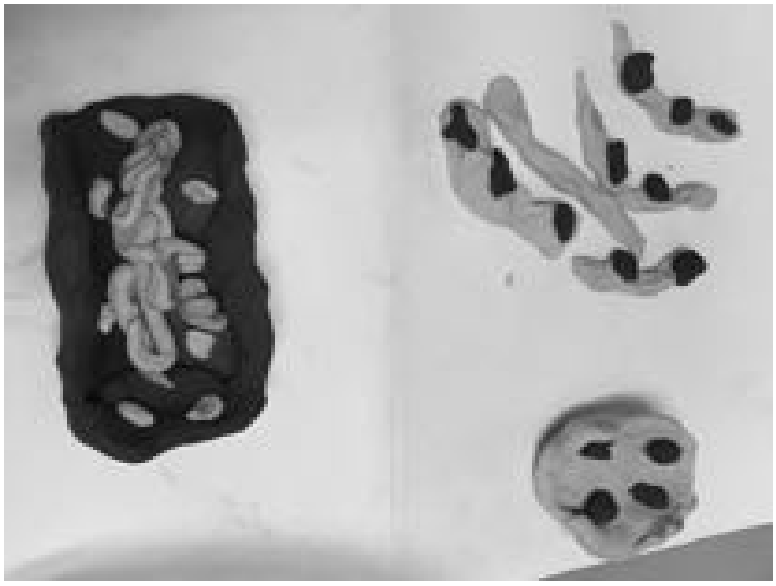
(Example of clay model with labels)



(Cell model in clay with detatiled components)



(Cell nucleus done in clay)



(Multiple examples of cell organelles created in clay)

APPENDIX F:

Treatment Group Student Survey

Student Survey (Treatment Group)
School number: _____ Student number: _____
Thank you for participating in the survey. Please read each statement and then fill in the circle that best indicates how much you agree or disagree.

1. The clay helped me understand the words.

O	O	O	O	O
Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree

2. I learned to appreciate the clay as I did more words.

O	O	O	O	O
Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree

3. I came to dislike using the clay as time went on.

O	O	O	O	O
Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree

4. I could picture the meaning of words better with clay.

O	O	O	O	O
Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree

5. Using clay was not necessary for me to understand the words.

O	O	O	O	O
Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree

6. Working with my hands helps me learn.

O	O	O	O	O
Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree

7 After making a few clay creations I felt I did not need to make anymore.

O	O	O	O	O
Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree

8. It was hard to work with the clay.

O	O	O	O	O
Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree

9. I felt that the clay did not improve my understanding of words.

O	O	O	O	O
Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree

10. Using clay helped me mentally picture things more clearly.

O	O	O	O	O
Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree

11. I think clay should be used in other classes too.

O	O	O	O	O
Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree

12. The clay helped with definitions more than simply using a dictionary or glossary.

O	O	O	O	O
Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree

13. Using the clay took too much time.

Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
O	O	O	O	O

14. Creating definitions of words in clay became faster and easier as I did more words.

Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
O	O	O	O	O

15. I wanted to work out more words than were on the list in clay.

Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
O	O	O	O	O

16. I stayed late or after school to work with the clay.

Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
O	O	O	O	O

17. I found myself looking forward to using the clay.

Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
O	O	O	O	O

18. I remembered words better after I used clay.

Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
O	O	O	O	O

19. I feel like I could turn any word into a clay creation.

Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
O	O	O	O	O

20. I could visualize what I wanted to make with the clay before I started.

Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
O	O	O	O	O

21. The clay was boring after a while.

Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
O	O	O	O	O

22. Every word presented a new challenge.

Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
O	O	O	O	O

23. I already knew what to do and the clay did not help clarify anything.

Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
O	O	O	O	O

24. Using the clay helped me with spelling.

Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
O	O	O	O	O

25. Using the clay helped me with pronunciation of the vocabulary words.

Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
O	O	O	O	O

26. I could not shape the clay into what I wanted.

O	O	O	O	O
Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree

27. I played with the clay more than I needed to when making clay representations.

O	O	O	O	O
Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree

28. The clay was messy.

O	O	O	O	O
Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree

29. I did not like cleaning up the clay area.

O	O	O	O	O
Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree

30. I had to work with the clay for a while until an idea came to mind, then I did it.

O	O	O	O	O
Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree

Please verify that you have answered every question. Thank you for participating in the survey.

APPENDIX G:

Control Group Student Survey

Student Survey (Control Group)
School number: _____ Student number: _____

Thank you for participating in the survey. Please read each statement and then fill in the circle that best indicates how much you agree or disagree.

1. The definitions and sentences helped me understand the words.

O	O	O	O	O
Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree

2. I learned to appreciate reading definitions and writing sentences as I did more vocabulary words.

O	O	O	O	O
Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree

3. I came to dislike writing sentences as time went on and I completed more words.

O	O	O	O	O
Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree

4. I could picture the meaning of words better by using sentences with the vocabulary word.

O	O	O	O	O
Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree

5. Using sentences was not necessary for me to understand the words.

O	O	O	O	O
Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree

6. Working with my hands helps me learn.

O	O	O	O	O
Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree

7. After writing a few sentences with a word I felt I did not need to write anymore.

O	O	O	O	O
Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree

8. It was hard to write sentences that demonstrated the meaning of the vocabulary word.

O	O	O	O	O
Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree

9. I felt that writing sentences did not improve my understanding of the vocabulary words.

O	O	O	O	O
Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree

10. Writing sentences helped me picture the meaning of the vocabulary words more clearly.

O	O	O	O	O
Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree

11. I wrote more sentences with the vocabulary words than I needed.

O	O	O	O	O
Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree

12. Writing sentences that show the meaning of the word should be used in other classes too.

O	O	O	O	O
Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree

13. Writing sentences helped with definitions more than simply using a dictionary or glossary.

O	O	O	O	O
Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree

14. Writing sentences took too much time.

O	O	O	O	O
Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree

15. Creating quality sentences using vocabulary words became faster and easier as I completed more of the vocabulary words.

O	O	O	O	O
Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree

16. I wanted to write sentences with more words than were on the vocabulary list.

O	O	O	O	O
Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree

17. I stayed late or after school to write sentences.

O	O	O	O	O
Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree

18. I found myself looking forward to writing sentences using the vocabulary words.

O	O	O	O	O
Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree

19. I remembered words better after I wrote sentences using the vocabulary words.

O	O	O	O	O
Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree

20. I feel like I could write sentences with any word.

O	O	O	O	O
Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree

21. Writing sentences was boring after a while.

O	O	O	O	O
Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree

22. Every word presented a new challenge.

O	O	O	O	O
Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree

23. I already knew the word and writing sentences did not help clarify anything.

O	O	O	O	O
Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree

24. Writing sentences helped me with spelling of the vocabulary words.

O	O	O	O	O
Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree

25. Writing sentences helped me with pronunciation of the vocabulary words.

O	O	O	O	O
Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree

Please verify that you have answered every question. Thank you for participating in the survey.

APPENDIX H:

Institutional Review Board Approval

Institutional Review Board (IRB)
for the Protection of Human Research Participants

EXPEDITED PROTOCOL APPROVAL

PROTOCOL NUMBER: IRB-035266-2017

RESPONSIBLE RESEARCHER: **Dr. Matthew Carter**

SUPERVISING FACULTY: **Dr. Daesang Kim**

PROJECT TITLE: ***Use of Clay in Vocabulary.***

APPROVAL DATE: **01.12.2018**

EXPIRATION DATE: **01.11.2019**

LEVEL OF RISK: ☒ Minimal ☐ More than Minimal

TYPE OF REVIEW: ☒ Expedited Under Categories 6 & 7 ☐ Convened (Full Board)

CONSENT REQUIREMENTS:

- ☒ Adult Participants – Written informed consent with documentation (signature)
- ☐ Adult Participants – Written informed consent with waiver of documentation (signature)
- ☐ Adult Participants – Verbal informed consent
- ☐ Adult Participants – Waiver of informed consent
- ☒ Minor Participants – Written parent/guardian permission with documentation (signature)
- ☐ Minor Participants – Written parent/guardian permission with waiver of documentation (si
- ☐ Minor Participants – Verbal parent/guardian permission
- ☐ Minor Participants – Waiver of parent/guardian permission
- ☐ Minor Participants – Written assent with documentation (signature)
- ☒ Minor Participants – Written assent with waiver of documentation (signature)
- ☐ Minor Participants – Verbal assent
- ☐ Minor Participants – Waiver of assent
- ☐ Waiver of some elements of consent/permission/assent

APPROVAL: This research protocol is **approved** as presented. If applicable, your approved consent form(s), bearing the IRB approval stamp and protocol expiration date, will be mailed to you

via campus mail or U.S. Postal Service unless you have made other arrangements with the IRB Administrator. Please use the stamped consent document(s) as your copy master(s). Once you duplicate the consent form(s), you may begin participant recruitment. **Please see Attachment 1 for additional important information for researchers.**

COMMENTS:

EXPEDITED PROTOCOL APPROVAL REPORT

Attachment 1

ADDITIONAL INFORMATION FOR RESEARCHERS:

If your protocol received expedited approval, it was reviewed by a two-member team, or, in extraordinary circumstances, the Chair or the Vice-Chair of the IRB. Although the expediters may approve protocols, they are required by federal regulation to report expedited approvals at the next IRB meeting. At that time, other IRB members may express any concerns and may occasionally request minor modifications to the protocol. In rare instances, the IRB may request that research activities involving participants be halted until such modifications are implemented. Should this situation arise, you will receive an explanatory communiqué from the IRB.

Protocol approvals are generally valid for one year. In rare instances, when a protocol is determined to place participants at more than minimal risk, the IRB may shorten the approval period so that protocols are reviewed more frequently, allowing the IRB to reassess the potential risks and benefits to participants. The expiration date of your protocol approval is noted on the approval form. You will be contacted no less than one month before this expiration date and will be asked to either submit a final report if the research is concluded or to apply for a continuation of approval. It is your responsibility to submit a continuation request in sufficient time for IRB review before the expiration date. If you do not secure a protocol approval extension prior to the expiration date, you must stop all activities involving participants (including interaction, intervention, data collection, and data analysis) until approval is reinstated.

Please be reminded that you are required to seek approval of the IRB before amending or altering the scope of the project or the research protocol or implementing changes in the approved consent process/forms. You are also required to report to the IRB, through the Office of Sponsored Programs & Research Administration, any unanticipated problems or adverse events which become apparent during the course or as a result of the research and the actions you have taken.

Please refer to the IRB website (http://www.valdosta.edu/ospra/HumanResearchParticipants.shtml) for additional information about Valdosta State University's human protection program and your responsibilities as a researcher.

APPENDIX I:

Teacher Interview Questions

Participating Teacher Interview Questions
Unit: Cells Genetics

1. How did using clay affect student learning?

2. How was the use of clay different for your students than other methods of vocabulary instruction?

3. Was classroom management different when students used clay? How so?

4. What were the challenges to using clay in the classroom and how were they met by you?

5. What were the benefits to using clay in the classroom?

6. How did you prepare for your lessons when clay was in your lesson plans?

7. What changes should be made with the study as you see it?

8. How were the logistics of classroom set-up altered when using clay?

9. (If the same teacher for both classes) How would you compare learning between the treatment class and control class?

10. How could clay be used in other disciplines or subjects?

APPENDIX J:

Teacher Demographics Survey

Teacher Demographics Survey

School A School B School C

Teacher A Teacher B Teacher C Teacher D

Please complete the following

Sex: Male: _____ Female: _____

Race: White: _____ Black: _____ Hispanic: _____ Asian: _____ Other: _____

Years teaching high school: _____

Years teaching science: _____

Years teaching biology: _____

Please list all of your degree(s) (do not include year of graduation or school):

_____

_____

_____

_____

Thank you for your participation!

APPENDIX K:

Pretest, Posttest, Retention Test for Cells Unit

Biology Assessment – Cell Unit (___ Clay or ___ Sentences)

Gender: Female____ Male____ **Race:** White ____ Black____ Hispanic____ Asian____ Mixed____

This test uses analogies. Analogies relate two items, actions, or systems.

Example A. Cat : Dog :: Meow : _____

a. Purr **c. Bark**
b. Kitten **d. Puppy**

The correct answer is c. Bark. The analogy is comparing how both animals make sound.

Example B. Ford : Cars :: _____ : Graduates

a. Chevy **c. Classes**
b. High School **d. Pick-up Trucks**

The correct answer is b. High School. The analogies relate what Ford and schools produce.

Circle the best choice for each pair of analogies.

1. Active Transport: Swimming upstream :: _____ : salmon
   a. Sodium ions c. Trout
   b. Solvent d. Cell Membrane

2. Cell Membrane : Cell :: _____ : House
   a. Door c. Wall
   b. Window d. Roof

3. Perfume : Diffusion :: Ions : _____
   a. Calcium c. Osmosis
   b. Sodium d. Hypertonic

4. Protein : Baseball :: Endocytosis : _____
   a. Bat c. Glove
   b. Basketball d. Base

5. Organs : Organelles :: _____ : Eukaryote cell
   a. Liver c. Organism
   b. Organ system d. Population

6. Lemon : Pucker :: _____ : Cell Shrinkage
   a. Isotonic c. Hypotonic
   b. Hypertonic d. Osmosis

7. Lipid bilayer : Cell :: _____ : Human
   a. Skin c. Tears
   b. Tongue d. Clothing

8. Principal : _____ :: School : Cell
   a. Nucleotide c. Secretary
   b. Nucleus d. Teacher

9. _____ : Whole :: Organ system : Organism
   a. Organelles
   b. DNA
   c. Parts
   d. Species

10. Bricks : House :: Macromolecules : _____
   a. Organelles
   b. Metaphase
   c. DNA
   d. Carbohydrates

11. Water : Osmosis :: People : _____
   a. Trains
   b. Children
   c. Diffusion
   d. Isotonic

12. Coins : Pocket :: Genetic Material : _____
   a. Eukaryote cell
   b. Prokaryote cell
   c. Lysosome
   d. Vacuole

13. Protein : Protein channel :: _____ : Street
   a. Cars
   b. Pavement
   c. Ions
   d. Curbs

14. Ribosomes : Rough Endoplasmic Reticulum :: _____ : Deer
   a. Antlers
   b. Sunshine
   c. Ticks
   d. Smooth Endoplasmic Reticulum

15. Airport security : Selective permeability :: People : _____
   a. Travelers
   b. Cell membrane
   c. Cell Wall
   d. Molecules and Ions

16. Explain the functions of the cell wall :

_____
_____
_____

17. Fully explain how cells react within a hypotonic solution:

_____
_____
_____

18. How does passive transport work?

_____
_____
_____

19. How does exocytosis work?

_____
_____
_____

20. Compare chloroplasts to mitochondria (include at least one similarity and one difference):

_____

_____

_____

APPENDIX L:

Pretest, Posttest, Retention Test for Genetics Unit

Genetics Analogy Assessment (___ Clay or ___ Sentences)

Gender: Female____ Male____ **Race:** White ____ Black____ Hispanic____ Asian____ Mixed____

This test uses analogies. Analogies relate two items, actions, or systems.

Example A. Cat : Dog :: Meow : _____

c. Purr **c. Bark**
d. Kitten **d. Puppy**

The correct answer is c. Bark. The analogy is comparing how both animals make sound.

Example B. Ford : Cars :: _____ : Graduates

a. Chevy **c. Classes**
b. High School **d. Pick-up Trucks**

The correct answer is b. High School. The analogies relate what Ford and schools produce.

Circle the best choice for each pair of analogies.

1. _____ : Eye color :: Sun, temperature, and moisture : Weather
   a. Alleles c. Heterozygous
   b. Chloroplasts d. Homozygous

2. Homozygous : Alleles :: _____ : Babies
   a. Fraternal twins c. Male siblings
   b. Identical twins d. Female siblings

3. _____ : Telophase :: 3 : 4
   a. Prophase c. Anaphase
   b. Metaphase d. Cytokinesis

4. Chromosome : Genetic information :: Cell Phone : _____
   a. Screen c. Apps
   b. Case d. Charger

5. Crossing over : Mixture of characteristics :: Shopping : _____
   a. Steak c. Eggs
   b. Soda d. Vegetable salad

6. Cell : Mitosis :: Glass of water : _____
   a. Halving of the water c. Pouring water into two equal cups
   b. Doubling the water d. Pouring water into two unequal cups

7. Board splitting in two : Karate :: Two new cells : _____
   a. Prophase c. Cytokinesis
   b. Telophase d. Photosynthesis

8. Tallness : Tall allele :: _____ : Genotype
   a. Recessive trait c. Recessive allele
   b. Phenotype d. Diploid cell

9. Hydrogen and Oxygen : Water :: Genes from parents : _____
    a. Diploid cell
    b. Haploid cell
    c. Ice or steam
    d. Peroxide

10. Blue Eyes : _____ :: Brown eyes : Dominant trait
    a. Dominant trait
    b. Widow's peak
    c. Recessive trait
    d. Red hair

11. Students : _____ :: Genes : Punnett square
    a. Chromosomes
    b. Career Day
    c. Gene Pool
    d. Class schedule

12. Blueprints : House :: _____ : Cells
    a. RNA
    b. DNA
    c. Polypeptide chain
    d. Protein

13. Gene : Chromosome :: _____ : Lawn
    a. Soil
    b. Weeds
    c. Blades of grass
    d. Fertilizer

14. Rewriting : English to French :: _____ : DNA to RNA
    a. Decoding
    b. Encoding
    c. Transcription
    d. . Translation

15. Heterogeneous : Biology :: _____ : Baking
    a. Two brownies
    b. One brownie
    c. Two slices of pie
    d. One brownie and one slice of pie

16. Compare meiosis to mitosis including at least one similarity and one difference.
    _____
    _____
    _____

17. What is the purpose of a haploid cell?
    _____
    _____
    _____

18. How can a recessive trait become visible?
    _____
    _____
    _____

19. What occurs during prophase?
    _____
    _____
    _____

20. What is the purpose of translation occurring in cells?

_____

_____

_____