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A Statistically Significant Determination from Pretest to Posttest in Knowledge of Electrophoresis Concepts

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A STATISTICALLY SIGNIFICANT DETERMINATION FROM PRETEST TO POSTEST IN KNOWLEDGE OF ELECTROPHORESIS CONCEPTS

by

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ABSTRACT

A STATISTICALLY SIGNIFICAT DETERMINATION FROM PRETEST TO POSTEST IN KNOWLEDGE OF ELECTROPHORESIS CONCEPTS

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The statistical significance from pretest to posttest of 109 high school students constructing an electrophoresis chamber or not was explored. The students tested were from six intact biology classrooms. Three classes were treatment groups, and three were control groups. The three biology teachers each taught a control and treatment group classroom. Except for building the electrophoresis chamber, students in both groups received identical instruction and testing. Pre- and posttest data was examined by means of a content valid test constructed by the researcher and biology teachers.

In order to examine the statistical significance from pretest to posttest in knowledge of electrophoresis concepts among students who constructed the electrophoresis chamber or not, an analysis of covariance (ANCOVA) was utilized. The final results showed a statistical significance but only just; therefore, the knowledge increase between students constructing the chamber compared to students who did not was marginal.

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DEDICATION

This dissertation is dedicated primarily to my mother and father because their continuous and positive reinforcement my entire life on the importance of a good education made this all possible. This dedication is also extended to my wife and children. I hope they one day understand the sacrifices made while away from them, and this will inspire my children to pursue a higher education.

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Table 1 - INTRODUCTION

In terms of educational theory, Phillips (1995) reasoned that constructivism contains differing sects intent on studying humanity's origins. These origins, designed by individual humans, are not believed to contain embedded cognitive abilities or acquired knowledge; yet, they have the ability to perceive direct comprehension of learned development. Murphy (1997) suggested that constructivism is knowledge embedded theoretically with other learning disciplines, such as psychology and philosophy, which lack methodology for translating knowledge into a teachable approach for learning. With this understanding, the knowledge of how to exhibit or construct learning environments is fundamental to recognizing practical approaches to employing a constructivist's philosophy. Since human knowledge encompasses constructed knowledge regardless of the potential in a human's ability to learn, Smith (1992) surmised that all learning environments must adopt a philosophy of responding to and identifying how students ascertain knowledge, thereby adapting to the needs of the learner.

Hmelo-Silver, Duncan, and Chinn (2007) revealed that Lev Vygotsky and Jean Piaget's research laid the foundation for constructivism with past experience and social interaction as primary guiding factors. The ability to discover essential information rather than the information being provided creates a greater educational experience. According to Garbett (2011), active knowledge construction forming new understandings is prompted by the teacher's ability to discover a student's prior knowledge and past experience; otherwise, the capacity to grasp concepts is lost in context. It is fundamental to recognize constructivism's ability to allow curiosity to drive the way one views the world by applying past experience as a guide to the abstract or complex perspective. This knowledge not only informs but also questions and challenges educational practices less revealing to conjectural reasoning (von Glasersfeld, 1995).

The Mississippi Department of Education [MDE] (2010) intended inquiry to be integrated across all science content, including problem-solving, work-based evidence, and scientific actions, in order to induce investigations and explanations of the natural world. According to the National Institute of School Leadership [NISL] (2012), hands-on activities and exploring variables do not sufficiently describe a lesson as inquiry-based. Students must investigate phenomenon based upon evidence and reasoning to justify conclusions drawn from interpreting data.

Modern society literally revolves around scientific knowledge and advancements. Consider technological and medical innovations just within the past decade, such as Stem cell research, increased wireless technology, and social media access. This study is centered on a medical technological breakthrough known as *electrophoresis*. The Merriam-Webster dictionary defines electrophoresis as an electromotive force, which displays the motion of particles through a medium. When particles become charged in a fluidic electrical field, migration occurs toward an electrode or cathode dependent upon particle type (Electrophoresis, n.d.). Modern electrophoresis technological advancements can trace their origins back to Arne Telius, who is commonly known as the father of electrophoresis (Kyle & Shampo, 2005). These advancements led to engineering and technology students' increasing competition throughout the world, allowing for new job opportunities and investigative techniques. Identifying forensic evidence collected through soil samples from crime scenes and anti-biotic development are examples of the abundant applications of electrophoresis (Concheri et al., 2012).

Background of the Problem

The Mississippi Department of Education [MDE] (2010) has yet to adopt Common Core standards for science. Therefore, teachers develop lesson plans based upon the 2010 science framework. According to Alberts and Tuomi (1995), the Association for Supervision and Curriculum Development [ASCD] explained that Common Core is a comprehensive set of standards adopted by more than 40 states, whereby teachers across subject areas and state boundaries will work under common standards. These standards provide the tools for educators to prepare students to be college and career ready within a global community.

In order to prepare students for the Biology I state test, science departments create curriculum alignments with state objectives for the conceivable future. The science framework is designed to integrate inquiry as a fourth content strand, because applying inquiry within the biology content strands was the intent of MDE (2010). Even though Mississippi has not adopted Common Core Standards, the National Academy of Sciences (NAS) has published both a recommended framework as a first step for states toward Common Core Science Standards and the Next Generation Science Standards (NAS, 2012).

The Pedagogy of Inquiry Learning

As previously affirmed, the MDE (2010) designated inquiry as a fourth strand to compliment physical, Earth and space, and life content areas. In terms of pedagogy, Gott and Duggan (1995) revealed that scientific inquiry requires a combination of grasping facts and theories as well as knowledge of procedures. Conceptually, substantive evidence of analyzing data or evaluating practical work promotes inquiry-based learning.

This analysis of data as part of inquiry described how teachers tend to focus on practical tasks instead of developing inquiry as a methodology. Even though this was effective in increasing student knowledge, the researchers found no link between the learned objective and increased cognitive ability (Abrahams & Millar, 2008). Garrison and Kanuka (2004) discussed developing constructive hands-on inquiry learning through technology. Blending technology with inquiry is innovative yet time consuming; however, the potential benefits far outweigh any drawback. A hands-on science lesson must have rigor and discovery, or the lesson will not improve student achievement in science. Just by including a few simple instructional techniques, teachers can create more inquiry learning prospects. Howitt (2007) speculated that teachers who were not exposed to inquiry in the past are inclined to experience anxiety about their own efficiency when expected to implement and employ inquiry-based pedagogy in a classroom. Field experience extracted from pre-service teacher science courses can provide much needed exposure to teaching inquiry-based lessons. The potential for shaping our future teachers directly from their methods courses can bring to light the importance of pedagogical inquiry and increased efficiency toward science teaching (Bleicher, 2006).

Scientific Knowledge Relating to Electrophoresis Concepts

The NAS (2012) explained how scientific advancements in technology and engineering can provide pathways for students outside of conventional science courses. These pathways are at an application level, which serve to strengthen the engagement level by providing a platform into the scientific realm. For this study, electrophoresis is the scientific advancement that will be described. Including the concepts related to any electrical circuit, the primary electrophoresis concept that will be studied is identifying variants related to Sickle-Cell Disease (SCD). Some other common uses for electrophoresis include conducting paternity tests, detecting diseases, analyzing DNA, and identifying participants in a crime scene. DNA fragments are injected into a gel; the particles separate into distinct patterns whereby scientists can identify paternity or DNA ownership (Toth, Morrow, & Ludvico, 2009). Petr and Maier (2012) described how electrophoresis identifies microbial organisms such as E-Coli by detecting the cellular membrane's zeta potential. The zeta potential depicts the amount of electrical charge across a blood cell. When liquids flow through a negatively charged cell membrane, the charge increases, therefore distinguishing electrophoretic detection (Fike & van Oss, 1976). Doctors in Japan evaluated specific cancer cells using electrophoresis to discover different drug treatments (Funato & Takeda, 2005). Oztas, Ozdol, and Karaca (2011) used electrophoresis to study low-density lipoprotein (LDL). One of LDL's subgroups has been found to be a cause of coronary disease. Scientists were able to identify each LDL subgroup due to migration patterns within the agarous gel. One type of small, dense LDL displayed higher levels within a sample of coronary patients; however, the increase was not statistically significant. Regardless, cholesterol levels in the blood tend to be higher or lower depending on the concentration of lipoproteins, which exhibits some of the strongest evidence toward lipoprotein cardiovascular risk factors (Kamstrup, 2009). Along with a pedagogical view of learning thorough inquiry, this section provided an overview about some of the important roles electrophoresis plays in society and the scientific knowledge relating to electrophoresis concepts. Much of this scientific knowledge about electrophoresis has a profound effect on quality of life and medical research. The next section will provide a brief overview of the theoretical framework in which this study is based.

Theoretical Framework

There are two types of constructivism: *social* and *cognitive*. Due to the inquiry-based, cooperative exploration of SCD using electrophoresis, this study contained facets of each constructivist theory. Nevertheless, a comprehensive depiction of each theoretical aspect will appear in chapter II because insight into both strategies is necessary to facilitate an effective classroom. Regardless of the type, constructivism's overarching philosophy cannot be overlooked. When teachers build from prior knowledge attained through students' past experience, all aspects of constructivism are employed. These aspects must be realized by the teacher in order to progress student potential between providing information versus discovery (Wells, 1999).

Orstein and Hunkins (2004) revealed that Lev Vygotsky based his research on *Social Constructivism,* which focused on social and cultural interactions, where a student's psychological processes developed based upon enculturation into society. In a social constructivist setting, students work with one another and the teacher, forming a partnership of internalized knowledge (Vygotsky & Kozulin, 1986). In an attempt to depict a conceptual relativistic view of constructivism, Phillips (1995) illustrated how the world of human beings can affect knowledge created imperfectly when humans act and investigate in collaboration with nature and provide intelligent feedback. The implication that humans (students in this case) learn as a social group working in congruence with the teacher has challenged the traditional approach of teachers influencing the learning process. Ernest (1994) argued that the social construction of individuals form inseparable connections through learning interactions. Even if a true philosophical picture has been created, a wider perspective of constructed interaction must be established. This significant manifestation is primarily owing to human knowledge relativistic toward conceptual knowledge in terms of social perception. In dealing with the natural world, Searle (1995) portrayed constructivists as not comprehending fundamental truths about social constructivism itself for which reality in the natural world must first be socially constructed. Indeed, the temptation to give in and construct similar alternatives independently is powerful; eventually, one must come to terms with constraints within the natural world.

A pioneer in constructivist theory, Jean Piaget viewed the individual learner through a cognitive constructivist lens. Piaget surmised that humans construct knowledge from past experience rather than simply obtaining information and immediately understanding (Powell & Kalina, 2009). According to Piaget (1954), the cognitive development of students separates into different stages of maturation: *sensorimotor, preoperational, concrete, and formal*. Kant (1996) depicted the cognitive realm as a complex, conceptual, empirical process, where reasoning and understanding start with the senses. Kant (1996) described real-world experiences as people learning empirically from actual knowledge. Therefore, reason provided priority to understanding, allowing for experience to guide the learner through cognitive development. Morf (1997) considered cognitive knowledge to be an individual making sense of the world through life experiences. For example, a child interacting with surroundings would learn by first-hand experience. As time passes, the child could make future decisions based upon past experience by constructing previous knowledge. Lorsbach and Tobin (1992) portrayed constructivism as having expanded to surpass other theories, such as epistemology, general education, and even some science theories. In terms of education, individuals create cognitive structures to ensure meaningful dissemination of knowledge through dialogue. Through this dialogue and any other prescribed means, cognition is appreciable whereby perspectives are constructed by active learning from previous experience (Garrison, 1993). Meaningful active learning does not imply diminished teacher responsibility. In fact, the framework from knowledge constructed by students is communicated by the teacher. Distribution of knowledge is necessary for students to make connections and build upon assimilated facts. If deficiencies exist during assessment, teachers must account for misconceptions in order to recognize where to reapply previous knowledge (Svinicki, 1991). Finally, Strike (1987) supposed constructivism's popularity stemmed from views by epistemologists that the theory is naïve and unsophisticated in terms of teaching and learning; yet, the contribution to education will continue until a better alternative comes forth.

The previous section portrays a synopsis of the two types of constructivism: social and cognitive. Social constructivism's importance centers on learning through student interaction, where cognitive constructivism's focus is toward learning based on constructing prior knowledge. Both parts interconnect to support inquiry-based knowledge in which students learn by doing, students are engaged, and students discover knowledge with the teacher and past experience as a guide.

Statement of the Problem

While evidence exists concerning linkage between inquiry-based learning and electrophoresis concepts, which is proposed in the research question, there is not enough research measuring knowledge of electrophoresis concepts, demonstrating inquiry techniques or not, while identifying a specific blood disease (SCD). By investigating how the application of a student-constructed electrophoresis chamber will affect student knowledge of electrophoresis concepts with this approach, the researcher will add important data to the existing body of knowledge relating to these variables: student-constructed electrophoresis or not and knowledge of electrophoresis concepts.

In order for hands-on science to be considered inquiry, a scientific investigation must occur. Science lessons cannot be a simple activity including following steps in a lab manual without an in-depth exploration of the hypothesis (Bergman & Olson, 2011). NISL (2012) corroborated that studying variables through steps without justifying conclusions is an insufficient scientific endeavor. Lacking data interpretation or evidence-based phenomenon suggests inadequate pedagogical science. The constructivist's model for this inquiry depiction includes authentic education by nature of science and process as methodology. Healey (2005) referred to inquiry-based learning as the pedagogy, which fills the gaps in curriculum alignment between students and staff. Active learning must only take place in activities where the teacher introduces information but allows students to discover knowledge for themselves; otherwise, the activity cannot be considered inquiry-based. Johnson (2006) called procedures-based experiments cookbook science. However, inquiry-based investigation is just a start because how implementation occurs must be addressed. In other words, the quality of inquiry learning is directly related to engagement and authentic science practice. Herron (2009) discussed this same type of transformation into inquiry-based curriculum from that known as cookbook science. Herron (2009) explained how, previously, there were individual students simply following steps and now a science-rich collaborative environment is present, where students were encouraged to be competitive and work together. Chinn and Malhotra (2002) explained how cognitive development through authentic inquiry is the best way for students to acquire reasoning skills during science classroom activities. However, the science lesson must be structured so that students can be guided through the inquiry process to discover the different facets being examined. If an inquiry-based lesson is the preferred method in which to explore science, then the lesson must be authentic, appropriate, and contain questions constructed by the students through guidance from the teacher (NRC, 2000).

Purpose of the Study

The purpose of this study is to determine how the application of a student-constructed electrophoresis chamber into selected classrooms will affect knowledge of electrophoresis concepts. The researcher will add important data to the existing body of knowledge relating to these variables: (IV) student-constructed electrophoresis chamber or not and (DV) knowledge of electrophoresis concepts.

Research Question

Because an exploration of the variables could yield significant results adding to the body of knowledge, the resulting question will be researched:

Will the use of a student-constructed electrophoresis chamber result in a statistically significant increase from pretest to posttest in student knowledge of electrophoresis concepts?

This hypothesis will be tested from an examination of the research question: There will be a statistically significant increase from pretest to posttest in student knowledge of electrophoresis concepts in classes that use student-constructed electrophoresis chambers when compared to classes that do not use student-constructed electrophoresis chambers.

Delimitations

This study will be delimited by:

1. The participants will be comprised from six different high school classrooms from the South Mississippi regional area.
2. The selection of student participants, even with intact groups, will be comprised of a typical classroom.
3. The teachers who participate in the professional development will be trained in the implementation of constructing the chamber, knowledge of electrophoresis concepts, and Sickle-Cell Disease.

Limitations

The predicted limitations will be:

1. The researcher will rely on the individual teachers to implement the experiment as trained.
2. The participants will not be comprised of random samples, but intact groups normally occurring in the selected school.
3. The participants will originate from only one school.

Assumptions

The assumptions for this study will be:

1. The teachers will carry out the construction lesson with fidelity, steadfastness, and dedication.

2. During the professional development, the teachers will answer all questions and participate with integrity and in a professional manner.
3. The students will not be aware they are participating in a study.

Definition of Key Terms

The following terms are presented to assist the reader of this study:

Brooks and Brooks (1993) defined *Constructivism* as an applicable process of discovering concepts whereby the student poses questions toward evolving relevance for the learner.

Electrophoresis is a process where particles migrate and separate through different mediums at different rates allowing personnel to analyze results, thus giving mankind the ability to detect medical conditions and offer possible treatment possibilities (Vesterberg, 1989).

An *electrolytic solution* is a substance that when exposed to an electric field produces ions that allow for the transport of an electricity through the solution (Xu & Angell, 2003).

An electrophoresis chamber has two e*lectrodes: anode* and *cathode.* Negatively charges particles (*anions*) migrate toward the *anode,* and positively charged particles (*cations*) migrate toward the *cathode*.

Pedagogical content knowledge (PCK) refers to knowledge of the teaching craft and teacher wisdom (Shulman, 1987).

Agarose Gel is the gelatinous acrylamide medium prepared with buffer solution at a pH of nine. When electrified, particles migrate through the gel toward an electrode depending on the particle's charge (Jordan & Raymond, 1969).

As defined by NISL (2012), an *inquiry* lesson must have a balanced instructional model of an evidence-based, conceptual knowledge and an understanding of a phenomenon.

Millions of h*emoglobin* (Hb) particles are contained inside a blood cell and transport oxygen from the lungs to the rest of body (Herron, 2007).

The United States National Library of Medicine (NLM) identified *HbS*, *Sickle-Cell Disease* (*SCD*) as a homozygous condition in which oxygen carrying red blood cells sickle abnormally into a crescent shape. An inherited trait, SCD can cause painful episodes that can lead to major infections, stroke, or blindness (NLM, 2012).

Identified as *HbAS*, *Sickle-Cell trait* is a heterozygous condition in which blood cells typically show as normal; yet, they became sickled (form a sickle shape) at the onset of an attack caused by a drop in oxygen saturation levels. Subjects, who only have the trait, are asymptomatic most of the time. In other words, someone with only the trait lives a normal life until the oxygen saturation levels drop; the blood cells sickle, causing a sickle-cell crisis (Herron, 2007).

Summary

This study will explore how a student-constructed electrophoresis chamber in selected classrooms will affect knowledge of electrophoresis concepts. The researcher will add important data to the existing body of knowledge relating to these variables: (IV) student-constructed electrophoresis chamber or not and (DV) knowledge of electrophoresis concepts. This chapter has presented an overview of this dissertation proposal, while chapters two, three, four, and five will provide a review of the literature, research methodology, results, and discussion respectively.

Table 2 – LITERATURE REVIEW

In today's society, science and technology have never been more important because students are training for future careers that most cannot yet conceive. In a world where science and technology are fast paced, and communication is driven by an ever-changing social media entrenched in an interactive environment, learning must also keep up with the times. For these reasons, teachers must transform classrooms into an activity-based, interactive experience in order to uphold the demands of modern society. In what type of environment can teachers and students interrelate together so as to address societal demands for a well-rounded individual? Perhaps this is a learning environment where students are trained to think critically with intent and predict future outcomes based upon research and knowledge. To facilitate the increasing demand for inquiry-based learning, common frameworks are presently being established across curricula with the purpose of designing robust standards, which are authentic and provide clear expectations of proficiency that students require for success (Common Core State Standards Initiative, n.d.). In Mississippi, where Common Core State Standards (CCSS) are currently integrated into K-2, full implementation across all grade-levels is currently planned with the intention of cultivating creative environments of profound engagement, problem-solving skills, and incorporation of content across subjects (MDE, 2011). Following the idealism of Common Core in cooperation with the National Science Teachers Association, the NAS (2012) published that core ideas in engineering and scientific studies are at the heart of the Next Generation Science Standards whose principle concern is preparing students to fulfill roles in our technological and complex world.

While the importance of science education is not disputed, pedagogical methodology varies between researchers believing in constructivism—hands-on learning and discovery-based practices—and researchers providing evidence in support of the different facets of inquiry. Constructivism, primarily founded upon the works of Jean Piaget (cognitive) and Lev Vygotsky (social), ascertained that students learn by constructing knowledge based on past experiences through thought processes and social interactions. Liu and Matthews (2005) recognized constructivism's social interactivity as being necessary for active learning to occur. Moreover, students are not merely recipients of knowledge but active participants in the learning process. According to Hmelo-Silver et al. (2007), learners discovered critical evidence through observation instead of directly being given facts; in this manner, students can construct knowledge themselves. Rieber (1992) referred to constructivist learning domains as micro worlds. These micro worlds are comprised of enhanced learning centers where students make real-world connections through a discovery-guided environment.

In contrast, Mayer (2004) interpreted how constructivist teaching is not easily converted into active learning. Mayer argued that in order to promote active learning, only diversity from different pedagogical perspectives could facilitate student knowledge. Kirschner, Sweller, and Clark (2006) proposed that implementing unguided instruction without providing clear procedures ignores human architecture. This architecture is founded on the belief that novice learners must first be provided information directly, which explains the strategies students will later be expected to apply on their own. Gagne and Glaser (1987) described learning as students moving through different levels based upon knowledge directly acquired from a hierarchy of experts. This knowledge is gained progressively and integrated into structures until student comprehension attains expert status. The challenge constructivists face is that mainstream scientists value objective and impartial research where subjects are studied and phenomenon are investigated with neutral detachment instead of through the lens of a craftsman constructing and guiding based upon past knowledge (Mir & Watson, 2000).

Engaging students through intelligent, active participation is the best way to attain their interest. Learning must have meaningful purpose that encourages creativity, which draws from prior knowledge. With the prominence of portable wireless technology comes instant gratification that can be addressed by studying electrical properties through building electro-boards. Constructing devices introduces concepts such as voltage, charged particles, conductors, insulators, and completing an electrical circuit (Ducharme & Dixey, 2000). Teaching biotech related concepts such as gel electrophoresis is fueled by an increase in job opportunities, innovation, and the identification of medical conditions. Pomfret, Gurwattan, and Sillay (2013) conveyed how the agarose gel used in electrophoresis is now a source for brain research due to the gelatinous nature of the medium. In fact, the University of Wisconsin's medical center is currently tracking the feasibility of practicing neurosurgical techniques employing gel electrophoresis. Funato and Takeda (2005) reported how modification of a standard gel electrophoresis technique, called real-time polymerase chain reaction (RT-PCR), was used to quantitatively assess the resistance to specific cancer cell treatments. As said by the researchers, treating acute myeloid leukemia (AML) frequently fails due to Multidrug treatments (MDRs), so real-time data was needed to evaluate resistance to the newer multidrug resistance-related protein-1 (MDR1) treatments (Funato & Takeda, 2005).

This review of literature is presented to describe a comprehensive illustration of the variables: (IV) students constructing an electrophoresis chamber or not and (DV) knowledge of electrophoresis concepts. The chapter is organized into three major sections: (a) theoretical framework, (b) the pedagogy related to constructing the electrophoresis chamber, and (c) scientific knowledge related to electrophoresis concepts. The source of this proposal is based upon the theory known as "Constructivism." A comprehensive description of this theoretical framework supported by a complete description and supporting research is included in this chapter.

Theoretical Framework (*Constructivism*)

The foundation of this review relies on the learning theory known as constructivism. There are innumerable theorists that discuss constructivism in great detail, which can be applied to a K-12 classroom setting. Throughout the educational realm, there are currently two primary constructivist disciplines: *social* and *cognitive*. In order to apply constructivism, insight into both strategies is important for an effective classroom. Even if both theories are fundamentally different, successful employment of each can assist students in utilizing the main learning elements from each discipline (Powell & Kalina, 2009).

Social Constructivism

Known as the father of social constructivism, Lev Vygotsky (1896-1934) espoused collaboration and interaction as the integral components of social constructivism (Orstein & Hunkins, 2004). Vygotsky was an advocate for formal education based on the belief that students could learn under proper educational guidance and psychological tools. This proper educational guidance is cultivated from sound methodological pedagogy during critical proximal zones of development. Vygotsky (1962) explained how a child in this zone has an intentional tendency toward intellectual language and competence acquisition once supplementary actions are imitated. These actions reflect a child's tendency to utter early developmental words and gestures. Because words and gestures alone work together to demonstrate this important moment in the child's behavior and social development, Vygotsky portrayed progressive tendencies as learning to build on prior knowledge or scaffolding.

Based upon Vygotsky's work, Wood, Bruner, and Ross (1976) explained that scaffolding occurs when a student reaches academic independence after working closely with peers at a higher developmental stage. In essence, scaffolding denoted guiding students at early stages and slowly removing support until learners could support themselves. In terms of inquiry, scaffolding in early educational stages could be highly emphasized with the instructor asking the majority of questions. However, Morgan and Brooks (2012) found that many teachers believe that an inquiry lesson has the students asking the majority of questions about their own experiment. Yet minimal instructor guidance can frustrate even the highest achieving student without at least marginal prompts. Ramirez (1974) depicted this zone as an indicator of extraordinary magnitude that students can educationally achieve at higher levels than if left to informal education. Bruner (1961) explained that active student participation increases intellectual prowess allowing augmented problem solving skills by enacting viable memories. Nevertheless, teaching students to become better thinkers by effective teachers can displace learners from one educational level to the next, since the cognitive function of developing humans occurs within the social environment (Vygotsky, 1962).

According to Eggan and Kauchak (2004), social constructivism is knowledge constructed through a collaborative process of equal sharing of information. Collaboration is key to constructing information rather than obtaining this information individually. Kukla (2000) believed that pre-existence of reality is a euphemism culturally constructed by social invention of societal activities. In the course of these activities, reality lays undiscovered without active participation and social invention. Thus, students enthusiastically gain insight as members of the group instead of as individuals. This insight challenges the traditional concept of the teacher leading instead of the social constructivist model of the teacher as a facilitator (Phillips, 1995). During a lesson, the teacher and student are similarly involved in the learning experience. The students and teacher socially compare each other's viewpoint of the truth, creating a compelling dynamic whereby beliefs are shaped into coherent meaning and understanding. The importance of constructivism's social nature is distinguished by the inherent emphasis placed on active student involvement (von Glaserfeld, 1982).

Shashidar (2011) called social constructivism a "metaphor of the mind" in which the self is not only viewed as an individual but also connected socially among a broader context (p. 3). This context, being a social phenomenon, has broader implications comparatively with the mind being a social, collective entity, where creative interactions are constructed through dialogue and shared participation. Experiences generated through individual social construction are shared collectively. Therefore, these shared experiences are constructed into a worldview from which the cultural and social perspective portrays value (Ernest, 1999). Bigge and Shermis (2004) described social constructivism as critically thinking by means of thought and generalized concepts.

These concepts give teachers the necessary tools in which to prepare students to become proficient at communicating, thinking, and learning by inquiry. Communicating informally and formally through questioning activates prior knowledge and individually includes students in the discovery process. Activating prior knowledge during the questioning and collaboration process ensures effective teaching strategies within the constructivist model. Scott (2012) found that using a social constructivist approach encourages students in music class to become active participants getting involved in the learning process. Scott applied constructivism to allow students not just to receive music from the teacher but to use the material as an opportunity to create music outside the classroom. Harkness (2009) conducted a study with several middle school teachers using the social constructivist theory. Students were placed in small groups, two hours per day, and three days per week for one semester. The teachers would present a few problems covering various mathematical topics. The original problems were not intended to simply be solved but instead to act as a launching point in which new problems would arise to which students could construct resolutions based upon past experience. During such learning environments, students make connections, refine prior knowledge, and learn by conducting meaningful tasks (Cobb, Yackel, & Wood, 1992). Pedagogy such as this allowed students to see the real-world aspect of content. This content is not just straightforward, such as working problems in the book or on a worksheet. Students own the material by activating prior knowledge which in turn makes content authentic, which therefore helps students to appreciate the nuance of building mathematical relationships when problem solving (Lester & Masingila, 1998).

In response to meeting the challenges of career and professional development, the National Aeronautics and Space Administration (NASA) adopted the social constructivist model. NASA leaders had a need to develop world-class project managers, foster leadership development, and encourage advanced research concepts. Through social constructivism, NASA used storytelling as a way to bridge the gap between content knowledge and experience, while capturing the best dialogue through open communication. This style of learning entails involvement that draws from others to incorporate increased understanding and knowledge. Simply put, assistance from others during the learning process is essential in order for people to ascertain comprehension and grow professionally (Chindgren, 2008). Social interaction is the means to construct embedded knowledge that is shared in dynamic social communities. Participation in socially constructed and interactive organizations permits collective beliefs and culturally built practices to find a platform from which to transfer information among constituent members. Trust between organizational members serves to legitimize the collaborative efforts of the community, which are largely linked to organizational culture and common beliefs. Built through practice-based sharing and mutual respect for increased knowledge, such organizations are referred to as a community of practice model (Boyce, 1996). Implications for social constructivism within this model of joint enterprises and knowledge-sharing bind members into this community of practice, where team projects come to life among previously individualized departments. Members volunteer knowledge and colleagues are encouraged to clarify facts and information amid mutual respect for all ideas for the common good. These communities of practice model help participants grasp even the subtle contexts of each experience with relevance and value (Newell, Robertson, Scarborough, & Swan, 2002).

Cognitive Constructivism

Jean Piaget (1896-1980) was an innovator in cognitive constructivism. He described the cognitive domains of students through four stages of development: *sensorimotor, preoperational, concrete, and formal*. Piaget (1954) acknowledged that environment or genetics could alter the progression through which students develop even though the sequence itself may not change. Luhmann (1995) embraced Piaget's stance regarding differing structural developmental stages. Such order constituted a behavioral expectation with accommodations into a practical form, where viability and adaptation are distinctive between systems. In stage one (birth-two years), sensorimotor, students establish relations and realize objects are relatable to location. Environment influences students until simple reflex action advances into complex actions (Orstein & Hunkins, 2004). In stage two (two-seven years), preoperational, learning is more complex or symbolic. Using sensory information, students begin to discover factors about the surrounding environment and ask questions about the world in which they exist. Wadsworth (1996) referred to this as intuitive thought. This intuition that students develop allows definitive distinctions to be made about various and permanent objects and symbols, along with a familiarization of the environment in which a child grows and learns. In stage three (seven-11 years), concrete, students begin problem solving and building logical relationships from organized data. Intuitive thought is replaced by logic and inferences only if the child can draw from past experience as a guide (Langer & Killen, 1998). In stage four (11 -? years), formal operations, thinking on the abstract and analyzing spatial relationships are characterized by formal operations. Deducing, predicting, and drawing conclusions from theoretical data are possible due to direct correlation based upon past familiarity. Depending on intellect and maturation, students at the formal stage can make inferences without direct experience because of the ability for supposition construed by means of complex problems. How far a child can progress is limited only by experience and aptitude (Orstein & Hunkins, 2004).

From various types of learning that have been researched (*subliminal*, *implicit*, *etc*.), Reber (1993) questioned why constructivism has only emphasized the reactive process of learning. Humans acquire and act on knowledge by investigating their surroundings. When events occur, humans act or react; however, simply reacting may also be attributed to innate adaptive behavior. Therefore, certain responses are perhaps instinctive instead of merely learned. Reber (1993) continued that Piaget gave prominence to the reality that students do not simply react; students investigate the world around them. Piaget (1976) revealed that cognitive abilities exhibited by humans are unique among other living organisms due to humans' capacity to reason and perceive the world. Piaget (1976) suggested students typically mature by age 15 in intellectual capacities attributable to developing mental structures. Claxton (1997) specified the developing role genetics plays in cognitive and perceptual factors-not only in language skills but also in elements of previous experience not present by means of implicit learning. Learning may not be a true reflection of knowledge, which is explicit of constructivists; yet, awareness and understanding may apply conceptions independent of reality. This realistic human view is seen objectively as a positive truth that is perceived historically through the world as sociocultural opinion (Rorty, 1979). Similar viewpoints of reality are based upon assumptions and concepts that are of human construction. Still, reality itself does not assume existence based upon assumptions independent to the external world constructed from the human mind. As subjective epistemology goes, mapping the world after constructing relativistic arguments only serves to simplify the human cognitive mindset. What sense could be made between the human mind and reality is not clear if one assumes there is a reason for why things occur as they do. In any case, if constructivism reaches a place where common sense does not follow the realistic, independent view of existence, then and only then can the human mind justify denying cognitive doctrine (Searle, 1995).

Piaget (1954) initially veered constructivism toward the cognitive path when the idea of adaptive function was realized, which characterized knowledge through purposeful intent and reasoning. This view of knowledge only described its function, but did not necessarily describe how the knowledge occurred. Knowledge results from how the world is perceived; therefore, human sensory perception provides the feedback necessary for interaction regardless of human construction. In fact, constructed knowledge from independent reality can be investigated and discovered based on the observer's point of view (Fosnot, 1996). Smith (1992) revealed that constructivists attempt to motivate learners after analyzing the curriculum and creating engaging activities. This cognitive state is an effort to make sense of current educational concerns in order to construct satisfying learning environments for students. Still, Smith (1992) declared that learning does not require motivation due to the ease at which students acquire knowledge. Fosnot (1996) advocated that students must be allowed to explore meaningful, realistic investigations, such as learning by engagement where students can confirm predictions or discover new ideas that produce cognitive thinking not previously considered. Students need interaction and dialogue to incorporate newly acquired information; however, Claxton (1990) clarified that the primary realization about constructivism is that teachers can make a difference by facilitating current knowledge as a transition to what is learned next. This insight identifies teachers in need of additional development that encourages a well-rounded curriculum to enhance the learning environment for the student. Claxton (1990) believed constructivist teachers face obstacles of constantly trying to design lessons that contain valuable opportunities for learning.

Along with aligning curriculum so as to teach from a constructivist position, more knowledge about applying the constructivist theory across subject-areas would enrich any classroom setting. Shawer, Gilmore, and Banks-Joseph (2009) conducted a study to qualitatively explore different English as a foreign language teacher experiences, strategies, and curriculum. One particular note of interest was that some of the teachers constructed curriculum based on past experience. This in turn correlated directly to each student's background. So, the teacher designed and constructed curriculum from the learning styles of each student. This experience correlates with Vygotsky's belief where teachers guide instruction at the student's tempo, emerging through a zone of proximal development (Esler & Esler, 2001). Some teachers stated that the learning style of each student is key in order to building one conceptual step after another to support scientific inquiry as a classroom community (Pyle, 2008). Tomlinson (1998) summarized thoughts regarding textbooks driving cognitive development of students. The researchers found that textbooks restrict motivation and stifle cognitive growth for students and fail to stimulate creativity for teachers. An exploratory review of literature was conducted in order to investigate how career and technical education was guided within the educational realm. The review established support for the allegation that cognitive constructivism was most compatible with career and technical education. The researchers argued how cognitive thinkers use past experience to mentally create models, which is a central theme to constructivism. Creating these mental models gives way to a better understanding of career and technical core values. Finally, cognitive constructivism was predicted to be the principal pedagogy for career and technical education for years to come (Doolittle & Camp, 1999). Cognitive Load Theory (CLT) was compared to constructivist-based conditions (CON) in order to discover which learning approach was more efficient. CLT's different components (long term memory and working memory) and CON were investigated against longevity up to 11 days in order to test knowledge acquisition and conceptual understanding. The two approaches were analyzed by testing approximately 80 undergraduate students using numerous means, from virtual simulators to biographical questionnaires. The researchers discovered that using CLT improved efficiency when compared to CON. Even though there was a significant difference found in improved efficiency, the effect size was too low to actually translate into a practical significant effect of CLT over CON (Vogel-Walcott, Gebrim, Bowers, Harper, & Nicholson, 2011). Research into the differences between learning by a novice or an expert has influenced CLT development due to critical investigations in support of CLT into what De Groot (1978) described as schematic knowledge. De Groot argued that since novice learners are typically not as sophisticated in structuring learned information as less knowledge is stored in long-term memory. Conversely, advanced learners with more past experience tend to develop cognitive processes and expertise with much less cognitive load (Kalyugas, Rikers, & Paas, 2012). Mayer (2005) recommended further research comparing CLT versus constructivism. The reasoning was the influence such methods had on non-novice participants. If the population sample were predominantly made up of other than novices who typically have more expertise in the area in which the research is conducted, then the teaching strategies employed could have an adverse effect. This effect is due in part to infrequent amounts of research carried out on a high expertise population sample; therefore, more studies are needed to investigate this realm of constructivism.

This section revealed different approaches and theorists, which provided a theoretical framework for the constructivist model. Constructivism's traditional approaches, *social* and *cognitive,* are successfully implemented in multiple professions and research studies all over the world. Vygotsky realized social collaboration as the focal point for teaching, whereas Piaget believed that people gain knowledge through receiving information in which to attain higher cognitive levels. However, both theorists agreed that the main role of the teacher is a facilitator and classrooms should be student-centered, not teacher-centered (Powell & Kalina, 2009).

The Pedagogy of Inquiry Learning

There are many science topics taught to students from different approaches, philosophies, methodologies, and pedagogies. How do we know which subject matter is most important or even relevant? The issue then becomes not only what to teach students, but how to best convey the required content. As previously stated, there are literally hundreds of different practices from which to choose. However, there is a plethora of research describing a science methodology where students learn by doing. This section will portray an overview of supporting *science frameworks*, *inquiry* (pedagogy emphasis), and *Content knowledge.*

Framework Overview

According to the MDE (n.d.), full implementation and assessments across grade levels K-12 for CCSS are currently scheduled for school year 2014-2015. In order to prepare for implementation, the MDE began a program in 2011 of slow integration starting with K-2 with the higher-grade levels assimilating over the next two years. This multi-year progression of merging CCSS into the state framework is essential, because CCSS will eventually replace state frameworks with new common assessments. Regardless of CCSS approaching takeover, the state frameworks cannot be ignored, especially with accountability measures so ingrained in school districts. This is even more obvious for the fact that currently there are no CCSS for science (Common Core State Standards Initiative, n.d.). However, school districts are held accountable for college and career readiness with or without CCSS integration into science. On the national level, data on students who were not college and career ready is troubling. According to Shierholz, Sabadish, and Wething (2012), unemployment for college graduates was six percent versus 30% for students only with a high school diploma. Also, jobs in the field of science and engineering increased above those in other disciplines. Woellert (2012) reported a growth of science and engineering jobs three times of that for other job specialties. Students need to master skills by developing rigorous knowledge to be prepared for careers in the 21st Century. Only rigor and depth of knowledge in science across content areas and engineering can define post-graduate success. For post-secondary economic and personal success, a strong science background is essential for preparation toward an effective career (College Board, 2009).

The NAS (2012) published engineering and scientific benchmarks in order to usher our students toward college and career readiness. These benchmarks were developed to provide a conceptual framework for a common set of K-12 science standards for future adoption by each state education department. The committee, made up of members from the National Research Council, recognized the growing body of knowledge and teaching pedagogies regarding science inquiry and technology and the need for students to continually build on learned scientific practices (NRC, 2012). When inquiry is the utilized instructional practice, achievement gaps among different subgroups, such as race or socioeconomic status, decrease due to the amount of student engagement. Moreover, the statistical difference is negligible between performance bands among subgroups. Disadvantaged students' academic achievement actually shows more growth than mainstream students when inquiry was the methodology employed during science instruction (Lee, 2006).

Emphasizing Inquiry

Since 2010, inquiry has been listed as a separate content strand within the Mississippi science framework; however, inquiry was never intended to be separately measured. Inquiry's emphasis was always intended to be integrated as a natural component across all science content. Pedagogical connection to inquiry learning includes real-world scientific study, where students derive explanations and draw conclusions based upon hypotheses (MDE, 2012). Justice et al. (2007) revealed how many laboratory supply companies package step-by-step processes with the chemicals included. While these package deals help students replicate protocols currently used by scientists, opportunities for inquiry learning are missed. Just doing an experiment does not necessarily indicate the scientific methodology of discovery-based inquiry. Using such pre-made laboratory setups can actually take away from the inquiry process and scientific discovery. Maab and Artigue (2013) explained that inquiry learning should be student led and teacher facilitated, where scientific ways are introduced by way of discovery. Maab and Artigue (2013) illustrated how students actually should inquire about scientific work by connecting observation, data collection, and phenomena studies. This manner of student-centered discovery learning overcomes the one-way or direct diffusion of scientific information and questioning from teacher to student instead of student to teacher. Clark, Clough, and Berg (2000) conveyed that science teachers, who create lessons that are only hands-on, fall short on active, minds-on engagement. Where rigor and effective thinking is lacking, a hands-on science lesson may not improve student achievement in science. Just by including a few simple instructional techniques, teachers can create more inquiry learning prospects. To address the matter of creating inquiry, minds-on environments out of just hands-on learning, Colburn and Clough (1997) recommended utilizing the learning cycle's three levels: exploration, concept development, and application. By requiring students to draw conclusions, control variables, design tests, and question hypothesis, this learning cycle transforms a simple hands-on experiment into an inquiry minds-on discovery. Bergman and Olson (2011) discussed some tactics to employ that will upgrade a simple hands-on activity to inquiry. Asking thought-provoking questions and displaying data in a structured manner will create structure in an activity. Making use of organized data sheets allows students more in-group discussion time, because students trained to only follow step-by-step instructions can show frustration when first required to change their mindset. Teachers must also keep themselves from giving answers away too quickly during the different facets of a lesson. By merely asking a few guided questions and giving adequate wait time, students are likely to discover answers for themselves. During these discovery moments, introducing key words is an excellent time to address important vocabulary. Schmoker (2011) called this "authentic literacy," which means teachers invoke literacy with purposeful intent (p. 11). Bergman and Olson (2011) stated that in order for an activity to transform into inquiry, scientifically investigating a phenomenon takes precedent over a goal-oriented lab where students merely reach the final step of the laboratory exercise. Lambert (2007) characterized inquiry as both process and orientation with each component incorporating portions of the scientific method, which encourages drawing conclusions, problem identification, data interpretation, and experimental design. Many hands-on activities are promoted as inquiry; however, Sandoval and Morrison (2003) stated how research illustrating scientific knowledge must be overtly addressed or the phenomenon being explored will be reduced to little more than a novelty. Essentially, the phenomenon becomes something students can interact with in class while the actual significance is lost on the group. This misconception of just a hands-on activity being enough to ensure scientific rigor appears throughout the teaching profession. Too many lessons become more of a show without the fidelity scope necessary for investigative inquiry and discovery to occur. Johnson (2006) indicated that many teachers have limited knowledge as to what constitutes an inquiry lesson. In fact, there is widespread belief in the education community that conducting any hands-on or cookbook activity amounts to an authentic, engaging science lesson. Rogers and Adell (2008) proposed descriptive steps to convert any experiment into an inquiry based investigation. The researchers explained that cookbook labs do not engage students' exploratory or discovery abilities. The initial vocabulary or descriptive information, which typically is directly provided for the student, should be replaced with thought-provoking questions. These questions could easily be synthesized from the existing material already provided. Also, new vocabulary should not be introduced. Students should be allowed to discuss new words and ideas from the shared experiences that an enriched, inquiry-based activity can produce. Elstgeest (2001) suggested instructors pose questions that produce hypothesizing, predicting, and drawing conclusions. Volkmann and Abell (2003) recommended that students should be given the latitude to create the investigative questions from the materials provided. This way, students can take ownership of the experiment that in which will upgrade the activity from cookbook to inquiry-based.

Teaching Inquiry

Windschitl (2003) studied a group of preservice teachers in an attempt to gain a perspective of previous exposure to inquiry experiences. The preservice teachers participated in a unique inquiry-based classroom project wherein observations and journal writing were examined. The results revealed that inquiry training during science courses had little effect on the teacher's inquiry knowledge. In fact, results found that preservice teachers struggled even with forming a hypothesis, as well as probing students during guided inquiry questioning. Eick and Reed (2002) disclosed that teachers who do appear to grasp inquiry-based concepts find inquiry difficult to sustain and implement as pedagogy over a long period of time. The researchers reported that prior training on authentic, research-based methodology has a powerful influence on new teachers using guided inquiry through questioning and leading scientific investigations in their classrooms.

Herron, Davis, and Nelson (2009) explained that training teachers to use real-world, authentic investigation serves to rigorously incorporate students' active involvement in science. Consequently, Etheredge and Rudnitsky (2002) implied that teachers should take notice of age and ability level before allowing students to generate their own questions, even if inquiry is the final product. Changing from cookbook science to inquiry-based investigation is just a start. The real answer to inquiry is how implementation will occur because the quality of inquiry is directly proportional to student engagement of authentic science practices. Even if the sustainability of such scientific inquiry is an issue, prior exposure significantly increases the likeliness that new teachers will engage in inquiry more frequently than if inquiry training does not occur (Johnson, 2006). Teachers must take the lead in providing the necessary environment for inquiry to happen. Any activity requiring enhancements is the responsibility of the teacher to provide the guidance for students to build investigative inquiry skills. Therefore, more guided inquiry and scientific investigation training would enhance the science culture of any classroom (Windschitl, Thompson, & Braaten, 2008).

Alberts and Tuomi (1995) warned that improperly teaching with science kits could inhibit the quality of inquiry investigations. Confining the investigation only to the steps provided in the materials from the company that prepared the activity creates obstacles to inquiry and promotes an ineffectual learning environment. Inherently, teaching by kits also hinders opportunities for students to make connections based upon past experience or real-world events. Some teachers might also be constrained by pre-made materials due to feeling obligated to following the steps. As a result, this can prevent students from conducting a true investigation, whereby hypothesizing and predicting does not transpire (Olguin, 1995).

There is a growing concern among preservice elementary science teachers about their own effectiveness when required to implement inquiry-based pedagogy. These teachers are understandably anxious due to the responsibility of exposing students to a pedagogy they might not have ever experienced themselves. Unfortunately, teacher preparation courses may lack the ability to properly instruct preservice teachers in science inquiry pedagogy, which can cause teachers to become frustrated. This dissatisfaction can initiate apathy toward applying new practices such as inquiry (Howitt, 2007). One way institutions prepare preservice teachers is by way of requiring methods courses to encourage development of investigative skills that make use of a teacher's own experiences. This can allow teachers to develop lessons in what Echevarria (2003) referred to as building inquiry from teachable or anomalous moments: applying investigative techniques through inquiry in order to capitalize on lessons that do not go as previously designed. These anomalous moments invoke the employment of the very critical thinking and inquiry skills that teachers want students to utilize. Participation immediately becomes even more rigorous and authentic, which helps students become effective scientific learners. Haefner and Zembal-Saul (2004) reported similar findings when teacher candidates received inquiry-based training during their field experiences. The candidates were more likely to employ skills such as questioning and phenomenon investigations once in a science teaching position. The researchers discovered that using inquiry as a methodology produced teachers who are more open to strategies used in the science classroom. Training pre-service teachers to plan how these teachable moments might occur can lead to lesson enhancement and purposeful incorporation of nonstandard procedures to any scientific investigation. This translates to students being able to learn from their mistakes as a foundation of scientific discovery. The same can also be said about students' scientific investigations during trial and error. Allowing students to sometimes fail opens up room for authentic, inquiry-based learning (Saul & Reardon, 1996).

Content Knowledge and Biological Inquiry

The MDE (2010) intended subject area test items for Biology I are based upon objectives and competencies within the framework, where depth of knowledge is combined and explained with each objective. All the while, competencies are presented as a reference for teachers to incorporate flexible curriculum alignment while integrating inquiry. This way, inquiry lessons become the platform in which to teach pedagogical content knowledge. Even with the lack of adopted common standards for science, the MDE will rely on the state model regarding science framework for the foreseeable future. This notion of content knowledge for science teaching is nothing new; however, the new state mandated biology test produced by the MDE must inspire teachers to create innovative methods to teach science.

Shulman (1987) explained that pedagogical content knowledge (PCK) refers to knowledge of the teaching craft and teacher wisdom. This is indicated not necessarily by teacher intelligence of biology or other science topics, but instead on how students understand complex concepts and the difficulties students have learning and understanding. Shulman depicted PCK as a teaching knowledge base with seven primary categories. Three categories comprise content knowledge and four categories relate to pedagogy. Grossman (1990) implemented two of the major components of Shulman's work: knowledge of subject matter and student understanding of content-related topics. The researcher studied specific teacher education courses, conducted observations, reviewed educational leadership courses, and considered teaching experience. From this, Grossman refined PCK into context knowledge, content knowledge, and pedagogical knowledge, which encapsulate Shulman's previous PCK work. This perception of PCK represents teacher and student understanding of content area subject matter. Marks (1990) blended subject matter knowledge and pedagogical knowledge of PCK. Marks believed these two elements should be integrated by involving instructional media and subject matter content. Being that these two concepts are combined, this integrated PCK model renders the two elements indistinguishable. Adams and Krockover (1997) analyzed PCK of beginning science teachers and discovered that past experiences as a teacher assistant or student guided their understanding of science content and teaching strategies. The results explained that new teachers' knowledge development was guided by individual implementation of specific instructional strategies and conceptual understanding instead of procedures. Clermont, Borko, and Krajcik, (1994) examined PCK of instructional strategies and demonstration use of chemistry teachers. The researchers set up a workshop where novice and experienced teachers received training on providing content related demonstrations. The outcome confirmed what the researchers originally predicted: experienced teachers had a wider range of demonstrations to draw from for comparisons as opposed to a novice teachers. This result appears obvious; however, the novice teachers did display higher PCK growth once demonstrations became skill-oriented. Gess-Newsome and Lederman (1993) investigated preservice biology teachers' knowledge of subject matter over the course of one year of different teacher education courses. Results showed that most knowledge originated from the content area courses instead of education courses. However, as the year continued, both content and education PCK began to integrate into more of a coherent view of biology and education. Based upon observations, this integration did not translate into practice teaching because the complex nature of both content and practice for novice teachers conveys unique challenges. The researchers explained that expecting a preservice teacher to master both content knowledge in biology and instructional strategies is not reasonable until classroom management and teaching experience has been obtained.

Integrating inquiry into biological science classrooms is the response to studies showing the lack of educational practices and biological content. Researchers from Georgia Southern University, Regassa and Morrison-Shelter (2007) noticed a similar gap in knowledge of biology concepts and math skills. The researchers decided to revamp a molecular biology course by introducing inquiry-based methods through modeling and questioning, as well as crossing over into a math component to help students apply skills for solution preparation. Initially, the lecture and lab were two separate courses, but the researchers discovered students simply could not make the connection from the lab course to real application. The results illustrated that students' knowledge surpassed what the teacher expected. Wilke and Straits (2005) observed major issues in primarily teaching process skills using inquiry instead of the reverse. The researchers explained that students must first understand science processes in order to facilitate inquiry. The researchers have directly observed that students in their classes lack simple skills like measuring distance or volume. Therefore, process skill development occurred in segments in order to incorporate practical laboratory models so inquiry learning could take place. Rehorek (2004) investigated 30 biology students during a morphological section. The students were required to develop questions after researching assigned topics and then apply previous researched knowledge to answer self-constructed questions. Once the experiment was complete, students reported findings and attempted to convince peers that initial hypotheses were sound. The researchers confirmed that students' comfort level with active learning environments increased with additional exposure. Flory, Ingram, Heidinger, and Tintjer (2005) reported that biology teachers face a lack of funding for laboratory activities, which espouses many issues. Therefore, the researchers constructed a 50-minute activity using common plants from an easily accessible faculty greenhouse. The students were required to create a phylogeny matrix, analyze the evolutionary development, and recognize plant adaptation. The students used inquiry skills by comparing collected data from each group and offering explanations as to predicted evolutionary paths.

This section provided detailed discussions and research based upon different approaches and theorists that provided a theoretical framework for inquiry-based learning. Teachers must provide an atmosphere of discovery and investigation. As pedagogy, all hands-on activities must be evidence-based and engage in the study of a phenomenon rather than just collecting data. Along with observing, quantifying, and communication, an inquiry-based lesson must induce students to draw conclusions based upon analyzing data and predicting outcomes (NISL, 2012). This section described a brief overview of supporting *science frameworks*, *inquiry* (pedagogy emphasis), and *content knowledge.*

Scientific Knowledge Related to Electrophoresis

Science and technology permeate throughout the world. Literally every aspect of modern society revolves around scientific knowledge and advancements. Science touches human culture in ways our ancestors never considered, so we must keep up with modern technological demands or fall behind and become obsolete. Why is it important to have knowledge of scientific advancements? Which science concepts are important to study? For the purposes of this study, electrophoresis is the scientific advancement that will be described. In addition, this section will depict *important electrophoresis concepts* and conclude with a focus on *Sickle-Cell Anemia*.

Important Electrophoresis Concepts

Electrophoresis began in earnest in 1937 due to a chemist named Arne Tiselius who was awarded the Nobel Prize for his work on electrophoresis. The origins, which began years before, sprang from his doctoral work in the late 1920s. Early versions of the electrophoresis apparatus exhibited poor results when accounting for accurate measurements using heterogeneous materials in an electrical field. However, Tiselius did improve accuracy regarding temperature control and particle migration (Laylin, 1994).

Some common uses for electrophoresis include, but are not limited to, crime scene identification from blood samples, studying DNA in genetics research, drug therapy, identifying organisms, detecting diseases, and analyzing the RNA and DNA.

Likewise, investigative techniques are commonly used to verify paternity and document crime scene DNA or other genetic materials (Toth et al., 2009). Moreover, DNA is typically negatively charged; therefore, migrations of charged particles travel through the electrolytic solution toward the positive electrode. During migration, the fragments separate into distinct patterns whereby scientists can identify paternity or DNA ownership. During World War II, the wife of a German soldier had an affair with a Polish slave worker; ironically, the soldier was home on leave at the time. Soon after, the wife was sent to a concentration camp. While at the camp, the wife discovered she was pregnant but was unsure who fathered the child. Sixty years later, descendants of this affair wanted to know who had fathered them. Milde-Kellers et al. (2008) used electrophoresis to test DNA extracted samples from different family members' blood. The results were not conclusive; however, genotype yields produced a 200,000 ratio against the soldier being the father.

Petr and Maier (2012) expressed how different electrophoretic methods identify microorganisms. When the cellular structure dissociates, altering the zeta potential (*ionic charge*), the microbial cell membrane's surface changes causing a dissimilar dispersion pattern. These changes modify the migration pattern through electrophoresis allowing microbial (*E-Coli*) detection when compared to uniform cell-surfaced organisms. The electrophoresis technique called RT-PCR in which Funato and Takeda (2005) evaluated resistance to specific cancer cell treatments fails frequently due to standard Multidrug treatments (MDRs). A significant finding involving metallic ion exposure within the metabolic pathways was discovered as a link to contracting both Parkinson's and Alzheimer's disease. Electrophoresis permitted molecular protein investigation prior to the denaturing process, which facilitates decoding the toxic effects on the patient's metabolism (Han et al., 2012). A new electrophoretic test called capillary electrophoresis - mass spectrometry (CE-MS) classified host microbes from rats acquired through urine samples infused with antibiotics. Once the antibiotic treatments concluded, the researchers were able to identify 17 compounds with varying metabolic profiles (Kok et al., 2013). Pascali, Sorio, Bortolotti, and Tagliaro (2010) applied electrophoresis to measure the concentration of Lithium ions in serum for patients diagnosed with bipolar disorder. These Lithium cations (*positive charge*) migrate toward the cathode (*positive electrode*) and separate in a procedure called capillary ion analysis. This process separates the inorganic ions and determines the correct classification matrices. According to Turkez, Togar, and Arabaci (2011), oral care products such as Listerine are assumed to be safe; however, the toxicity of many common products is unknown. Using electrophoresis, the researchers tested Listerine's toxic potential. Human blood samples were mixed with varied Listerine concentrations, injected into the wells, and exposed to the electrical field. When compared to control group blood samples without Listerine, no significant toxic levels were displayed. Salviato et al. (2007) examined 82 hemophilia patients for causative mutations using an assortment of techniques, including gel electrophoresis. The analysis showed that 71% of the patients displayed one of the three different forms of gene mutations causing hemophilia A. In this study, electrophoresis's importance allowed the researchers to identify the severity of gene mutation as a blood disorder. Quintana et al. (2006) described that Chitotriosidase protein (ChT) chemically marks Gaucher's disease (GD). The researchers found that the concentration of ChT is directly related to the severity of this genetic disorder. Gel electrophoresis detected both the defective and mutant allele. The results demonstrated that the higher the ChT count, the more likely the patient has GD.

Focus on Sickle-Cell Anemia

Like GD, Sickle-Cell Anemia is detectable by the electrophoretic properties in hemoglobin that are produced when exposed to an electric field. The alleles separate and are identified by migration patterns, which determine if the patient has SCD, Sickle-Cell trait, or normal blood cells. SCD is a blood ailment inherited from parents and forms a C-shape that causes blood clots. According to the Centers for Disease Control and Prevention [CDC] (2012), over 90,000 Americans have SCD, which includes one in every 12 African Americans. People from across the world are debilitated by SCD. Data suggests that people with common ancestors from Africa, South America, Saudi Arabia, India, and Turkey are impacted the most. Between the years 1999 and 2002, SCD deaths among African American students dropped 42% due to the availability in 2000 of a new vaccine (CDC, 2012). Even with new vaccines and treatments, millions of people are people affected by SCD. In response, SCD research continues in all corners of the globe.

Rahimi et al. (2006) investigated genetic backgrounds of different groups from southern Iran. People from the southern provinces have a history of SCD variants. A common β-globin gene was identified through electrophoresis. Separation of the alleles categorized the most common mutations to be β^s. This chromosomal endpoint was prevalent in multiple tribes within the sampled region. The researchers traced the chromosome back to a time when Iran was known as the Sassanian Empire. Ogunbiyi, George, and Daramola (2003) revealed data suggesting a connection between SCD and the transverse digital crease (ETDC). The researchers studied the fidelity of EDTC as a detection tool for Nigerians compared to standard electrophoresis techniques. No significant correlation could be found using ETDC as a SCD detection tool. Hanchard, Hambleton, Harding, and McKenzie (2005) hypothesized that in areas where Malaria and SCD coincide within the same region of Africa, sickle- trait will decline where malaria declines. The researchers collected data in one 20-year increment in Jamaica, where Malaria and SCD shared similar affinity as in Africa. The populations were screened using electrophoresis to determine the frequency of the sickle allele. When comparing 20-year segments, there was not a statistically significant drop in the rate of Malaria/ Sickle trait. Ulasi (2008) described a Nigerian female with persistent hematuria. Once symptoms were relieved, no further abnormalities appeared. However, X-ray results displayed blood clots in the pelvis and urinary tract. Electrophoresis informed the doctors that the female had the Sickle-Cell trait (HbS). The data explained that 60% was HbS and 40% was normal (HbA). The evidence depicted a patient who is typically asymptomatic, but conditions were met that caused a portion of blood cells to sickle. Odunvbun, Okolo, and Rahimy (2008) expressed the need for a proactive SCD screening program to manage the care of newborns in order to reduce the infant mortality rate. Such screening programs in developing countries are atypical; moreover, parental support of prescreening in unknown. In order to establish frequency of SCD in infants and screening acceptability of mothers, the researchers recruited 630 mothers. 99.7% of mothers accepted the screenings; yet, only one half wanted to know their Hb phenotype. Using electrophoresis, 3% of the newborns tested positive for one of the variants of SCD. Renom, Mereau, Maboudou, and Perini (2009) stated that some Sickle-Cell detection and screening methods, like isoelectric focusing, are tedious and unreliable. In response, capillary electrophoresis (CE) has shown promise in detecting hemoglobin variants of newborns. The researchers evaluated loading capacity and Hb variant separation for 20 days. Upon the 20-day completion, few variants displaying similar migration to HbS (*Sickle trait*) were detected. Hammar et al. (2006) described how a 20-year-old female of African descent went into coma after being administered anesthetic for a minor medical procedure. Unfortunately, the female had a previously unknown Sickle-Cell variant detected by electrophoresis. The variant is believed to be the cause of the coma. Analysis confirmed that during the coma, over 80% of the patient's blood contained the HbS trait, which triggered the Sickle-Cell attack, therefore inducing the coma. Had the doctors and patient known of the abnormality, the patient might have survived. In areas of India where resources are limited and the population is at a higher risk of inheriting a SCD variation, Patra et al. (2011) conducted SCD screening on students three to 15 years old. Blood samples were collected and sent to a nearby medical school for electrophoresis testing. Upon test completion, the alleles were analyzed by phenotype. Surprisingly, only 0.2% of students registered HbSS (full SCD), while 9.4% registered as HbS. The researchers surmised the low numbers were due to death or marriage arrangements in order to reduce the chance of SCD. This actually reveals hope for high-risk populations that SCD can be controlled through proper screening techniques and tough family decisions. This researcher is not advocating arranged marriages by any means as a way to control SCD; however, this could be a real option in parts of the world where such arrangements are common.

Summary

This review of literature was presented in order to portray an all-inclusive illustration of the variables: (IV) students constructing an electrophoresis chamber or not and (DV) knowledge of electrophoresis concepts. The chapter was organized into three major sections: (a) theoretical framework, (b) the pedagogy related to constructing the electrophoresis chamber, and (c) scientific knowledge related to electrophoresis. Chapter One introduced the proposed study, Chapter Two reviewed literature linking related topics to electrophoresis, and Chapter Three will provide details of the pretest posttest quasi-experimental design methodology.

Table 3 - RESEARCH DESIGN AND METHODOLOGY

Problem and Purposes Overview

There is a multitude of existing research linking increased understanding of science concepts through hands-on learning. When students are driven to engage and explore science concepts, critical thinking skills are developed. With the advent of multiple technology platforms in which to hold student interest, stimulating problem-solving skills in science is vital. In today's world, instructors who focus on teaching science merely through processes and procedures are not serving a child's best interest. In this time of high stakes testing coupled with progressing to the next grade level, parents, administrators, and teachers have a duty to ensure the most conducive learning environment possible for all students. The type of setting previously described is an inquiry-learning environment. Mitchell, McCrorie, and Sedgwick (2004) confirmed this outlook when the researchers discovered nearly 85% of participants surveyed about their attitudes toward anatomy learning suggested that the hands-on time spent in laboratories was a more satisfying educational experience than lectures. Furthermore, students understood the value of how hands-on activities would increase knowledge of anatomical concepts (Mitchell et al., 2004). Johnston and McAllister (2008) confirmed that active learning promotes high levels of satisfaction, and hands-on interaction was the best motivator for applying conceptual knowledge and understanding.

With so many procedures and competencies to explore, there are limitless concepts, processes, and theories to study. One such concept is electrophoresis, which is a process where personnel can analyze migration rates of different sized and charged particles through a medium (Vesterberg, 1989). Known as the father of electrophoresis, Arne Tiselius's apparatus gave rise to modern electrophoresis techniques and devices used today (Kyle & Shampo, 2005). Electrophoresis is commonly used for identifying blood samples from crime scenes, conducting genetics research for brain infusion studies, diagnosing Parkinson's disease, mimicking poroelasticity of the brain, and developing catheter infusion (Pomfret et al., 2013). This research is important because this study will empower students to discover how to apply hands-on, inquiry-based learning to real-world applications by means of electrophoresis.

Research Question

Because an exploration of the variables, student-constructed electrophoresis, and knowledge of electrophoresis concepts could yield significant results which will add to the body of knowledge, the resulting question will be researched:

Will the use of a student-constructed electrophoresis chamber result in a statistically significant increase from pretest to posttest in student knowledge of electrophoresis concepts?

This hypothesis was tested from an examination of the research question:

$H_{1.0}$ There will be a statistically significant increase from pretest to posttest in student knowledge of electrophoresis concepts in classes that use student-constructed electrophoresis chambers when compared to classes that do not use student-constructed electrophoresis chambers.

Design

Quantitative

Because randomly assigning students into groups is not practical and could disrupt the learning environment of a school, a pretest posttest, quasi-experimental design will be employed for this quantitative study. The intact groups already present within classrooms necessitate this type of intact-group environment, because artificial groups cannot be created. The pre- and posttest actually resulted from a collaboration of the classroom teacher and researcher designed test. Accommodations for taking the tests will be made depending on a student's Individualized Education Plan (IEP) or Response to Intervention (RTI) plan.

Quasi-experimental designs allow for readily integrating into a current school's organizational alignment. Conversely, the quasi-experimental design is also susceptible to selection threats to internal validity. Regardless, quasi-experimental models are typical for research within school districts (Cresswell, 2005).

Population and Sample

Participants included three high school biology teachers and approximately 150 of their students based in a South Mississippi school district. No random selection of students took place. Six intact classes already established within the school's master schedule were chosen per the school principal's guidance. The classes selected were divided into three control groups and three treatment groups. Each teacher had a control group and a treatment group. The researcher donated a $25 gift card for Office Depot to each treatment group classroom teacher when the study was completed with the intention of promoting participation. The study took five days to complete. The treatment occurred during one period of instruction each day. Each instructor taught a control and treatment group in a class of the exact subject area each day, which controlled the teacher variable and eliminated teacher bias.

Procedures

All elements of the study were explained to the school's principal. After approval, a meeting with interested teachers was scheduled. At this meeting, the researcher fully explained the various segments of the study and encouraged participation. Soon afterward, the teachers undertook one day of professional development (PD). The researcher conducted this PD in order to instruct the teachers on how to build the electrophoresis chamber, all electrophoresis pertinent vocabulary terms, as well as why electrophoresis is important. Fidelity was established in two ways: a researcher-constructed observation instrument (*Appendix A*) used in the treatment and control group, and the teacher's lesson plans (*Appendix D and F*). Finally, the researcher was present during the treatment and control groups in order to provide assistance and ensure fidelity.

Observation Protocols

During each day of the experiment, the researcher and one other individual conducted observations to ensure fidelity. Along with the researcher, the second observer is currently an administrator at the school. Both the researcher and the second observer have conducted many classroom observations together in the past. Moreover, the second observer has a bachelor's degree in biology and has taught high school biology for 12 years. The observations were conducted during the entire treatment and control group class period. Two different observers were used in order to ensure inter-rater reliability. The observation instrument is a checklist that distinguishes between the control and treatment group. The instrument depicted whether or not the chamber was actually constructed. Having the two different raters is essential in establishing inter-rater reliability because bias can be negated in one or several raters by comparing observational score similarities or dissimilarities (Cresswell, 2005).

Control Group

Students in the control groups took a pretest to determine baseline knowledge of electrophoresis concepts (*ionic charges, trait identification, particle migration, electrical principles, predicting outcomes, real-world application, etc.)*. The answers to the pretest will not be disclosed until the experiment had concluded. The participating instructor introduced the concepts. Electrophoresis concepts were taught using slides, handouts, and YouTube demonstrations (Appendix F). The instructor displayed a real chamber for students to view. Students in the control groups only observed how an electrophoresis chamber works while learning about electrophoresis concepts. Upon conclusion of the treatment, a posttest was given to all participating students.

Treatment Group

The study took place during a three-day period. Students in the treatment groups took a pretest to determine baseline knowledge of electrophoresis concepts (*ionic charges, trait identification, particle migration, electrical principles, predicting outcomes, real-world application, etc.)*. The answers to the pretest were not disclosed until the experiment concluded. The participating instructor introduced the concepts. Instead of just viewing demonstrations, the students' learning was reinforced by constructing their own electrophoresis chamber (Appendix C and D). After prefacing these concepts and constructing the chamber, the students actually loaded solutions, injected samples into the wells, predicted outcomes, and viewed the particle migration through the buffer solutions in a chamber of their own design. The experiment simulates detection of Sickle-Cell Anemia. In place of real blood, colored dye samples were used. When exposed to electrolytic solutions, some colored dyes act similarly as actual blood samples without the need for special precautions that would accompany the use of any blood samples. These colored samples provided an authentic sense of a real-world laboratory setting, while combing a unique hands-on, inquiry-based experience. Upon conclusion of the treatment, a posttest was given to all participating students.

Data Collection

Construction of the electrophoresis chamber was implemented into three different classrooms over a period of approximately three days. Each participating teacher instructed a treatment and control group. The pretest on electrophoresis concepts was given before the study began to attain a solid baseline. After the experiment was concluded, a posttest containing the exact content as the pretest was given.

Professional Development

After meeting with the principal and selected teachers, PD for the selectees was scheduled for a one-day block of instruction. The professional development consisted of detailed instructions: which chemicals to use, how to make the agarous gel, and construction of the electrophoresis chamber. The PD also included details on why electrophoresis is important and real-life applications of electrophoresis (Appendix C and E). The teachers received PD on electrical currents, solution preparation, micropipette techniques, electrophoresis procedures, Mendelian genetics, and predicting and identifying genetic abnormalities in simulated blood samples.

The researcher conducted observations during each of the treatment and control classrooms while the study was being conducted in order to maintain investigative integrity. Based upon field notes and observational data from the observation instrument, re-training of the participating teachers would be conducted to ensure fidelity of the treatment if the researcher viewed that the treatment was not being carried out with steadfastness. This re-training would be conducted at the end of each workday to validate fidelity for the next day. To encourage participation, the researcher donated a $25 gift card for Office Depot to each treatment group classroom teacher once the final interviews have been completed.

Instrumentation

Original electrophoresis's development was derived based upon the work of Arne Tiselius, "The Father of Electrophoresis" (Kyle & Shampo, 2005, p. 32). The instrument which measured electrophoresis concepts is a pre- and posttest that was administered in the treatment and control group classrooms to test knowledge of electrophoresis concepts. This test was a collaborative effort between the teachers and the researcher (Appendix G). The researcher used teacher-constructed materials to measure knowledge of electrophoresis concepts because reliability and validity were already established. Any teacher-made test would be designed to "test" the content. One can assume that any teacher, new or experienced, would create instruments with the intent on measuring the content the teachers were, in fact, teaching to the students.

Electrophoresis Chamber

The students within the treatment groups constructed the electrophoresis by hand, made the agarous gel, injected the solutions, and observed the migrating particles. Building the chamber allowed students to apply the electrophoresis concepts taught by the instructor, rather than watching a demonstration and listening to lectures about electrophoresis (Appendix C).

Observation Checklist

Designed by the researcher, the observation instrument included steps containing the chamber construction process. A panel of experts established content validity in order to validate that students built the chamber in the treatment groups and would not build the chamber in the control groups (Appendix A).

Data Analysis

Quantitative data was collected. Students constructing the chamber or not is the independent variable and difference in knowledge of electrophoresis concepts is the dependent variable. Statistical significance was indicated by posttest results.

Quantitative

The mean was evaluated using an Analysis of Covariance (ANCOVA). SPSS statistical software version 17.0 was used to analyze the quantitative data.

Summary

In this chapter, the researcher endeavored to investigate the statistical significance of how a student-constructed electrophoresis chamber will lead to understanding of electrophoresis concepts. The researcher collected and analyzed quantitative data from three treatment groups and the three control groups in order to investigate the hypothesis and discuss the research question.

Table 4 – RESULTS

Introduction

The purpose of this study was to determine if knowledge of electrophoresis concepts were significantly affected whether or not students constructed an electrophoresis chamber. The chamber construction and subsequent results stem from an analysis of the inquiry-based lesson over time. This chapter presents the statistical results from a pretest posttest quasi-experimental design.

Analysis of Data Arrangement

The data produced by this study is presented first by a description of the participant groups. Next, an analytical overview summarizes the marginally significant indicator of change when measuring knowledge of electrophoresis concepts. Finally, the co-variant outcomes resulting from the research question and hypothesis as measured by the ANCOVA test are portrayed along with a corresponding examination of the variables. A precise summation of the data will bring this chapter to a conclusion.

Group Descriptions

Participants were students comprising six biology classrooms already established within the school, so random assignment was not a factor. In addition, three biology teachers were trained by the researcher during a PD day so as to instruct the students on electrophoresis concepts. Each teacher taught one control group and one treatment group. No additional demographic and descriptive data was considered for this quasi-experimental design.

Research Question

The relationship between knowledge of electrophoresis and hands-on science via a high school student population was ascertained from this investigation. Will the use of a student-constructed electrophoresis chamber result in a statistically significant increase from pretest to posttest in knowledge of electrophoresis concepts? The next section will present an explanation of the research instrument.

Instrumentation

Knowledge of electrophoresis concepts was measured by a teacher-made test in a collaborative effort between the biology teachers and researcher. The instrument was administered in each of the six classrooms a total of two times (pre- and posttest): preceding the lesson and at the conclusion of the experiment during the month of May 2012 the week before final exams. Students were not provided the answers to the test until the conclusion of the study.

Data Analysis and Summary

Overview

An Analysis of Covariance (ANCOVA) was the statistical test utilized to examine if there is a significant difference in knowledge of electrophoresis concepts whether or not students constructed an electrophoresis chamber during high school biology classes. Regardless of the methodology employed, teachers vary when it comes to strengths, weaknesses, or knowledge of the subject matter; therefore, the ANCOVA was selected instead of other statistical tests in order to account for the teacher variable, time, and group.

The primary results indicate that there was a statistically significant increase in electrophoresis concept knowledge from pretest to posttest when students constructed their own electrophoresis chambers by a co-variant analysis of F (1,88) = 3.915, p = .05 when controlling for the teacher variable, because group is a significant indicator of change. Additionally, the ANCOVA produced adjusted pre– and posttest means (Table 1) further controlling the teacher variable. However, the finding resultant was negligible when comparing the original means as a significant indicator of group effect and controlled teacher variable.

Research Question

Will the use of a student-constructed electrophoresis chamber result in a statistically significant increase from pretest to posttest in student knowledge of electrophoresis concepts?

Hypothesis 1.0

There is a statistically significant increase from pretest to posttest in student knowledge of electrophoresis concepts in classes that use student-constructed electrophoresis chambers when compared to classes that do not use student-constructed electrophoresis chambers. The expected outcome was that both treatment and control groups would increase from pretest to posttest, and the treatment group would increase significantly. The resulting conceptual knowledge increase was significant for student-constructed electrophoresis chambers, as illustrated by the ANCOVA in this study and produced F (1,88) = 3.915, p = .050. The measure of time-effect probability of less than .001 is associated with the covariant resulting effect F (1,88) = 52.507, p < .001, which established that there indeed was a change in time from pretest to posttest.

Table 1 displays participant data and mean scores. The control group increased mean scores from 42.74 to 64.82, while the treatment group grew from 47.64 to 69.79 (Table 1). Even though the treatment groups' mean posttest score tested higher as hypothesized, the substantial gain in knowledge of electrophoresis concepts between the groups revealed an insufficient variation. Graph 1 presents an incremental increase for both groups on a virtual parallel progression during the same time period. The researcher originally predicted that the treatment mean score would not be as comparable to the control group. Hence, the hands-on construction of the chamber did not have a major effect on knowledge according to the mean scores, even though the effect was significant. No significant effect for Time by group interactions was found $F\ (1,88) = .009$, $p = .926$. The parallel lines on graph 1 demonstrate the similar progression the means undertook over time from pretest to posttest.

Table 1

Summary of Descriptive Group Statistics

	Group	Mean	Std. Deviation	N	Adjusted Means
Pretest	1 treatment	47.64	14.287	53	47.781
	2 control	42.74	15.250	38	42.542
Posttest	1 treatment	69.67	21.128	53	70.044
	2 control	64.82	18.521	38	64.465

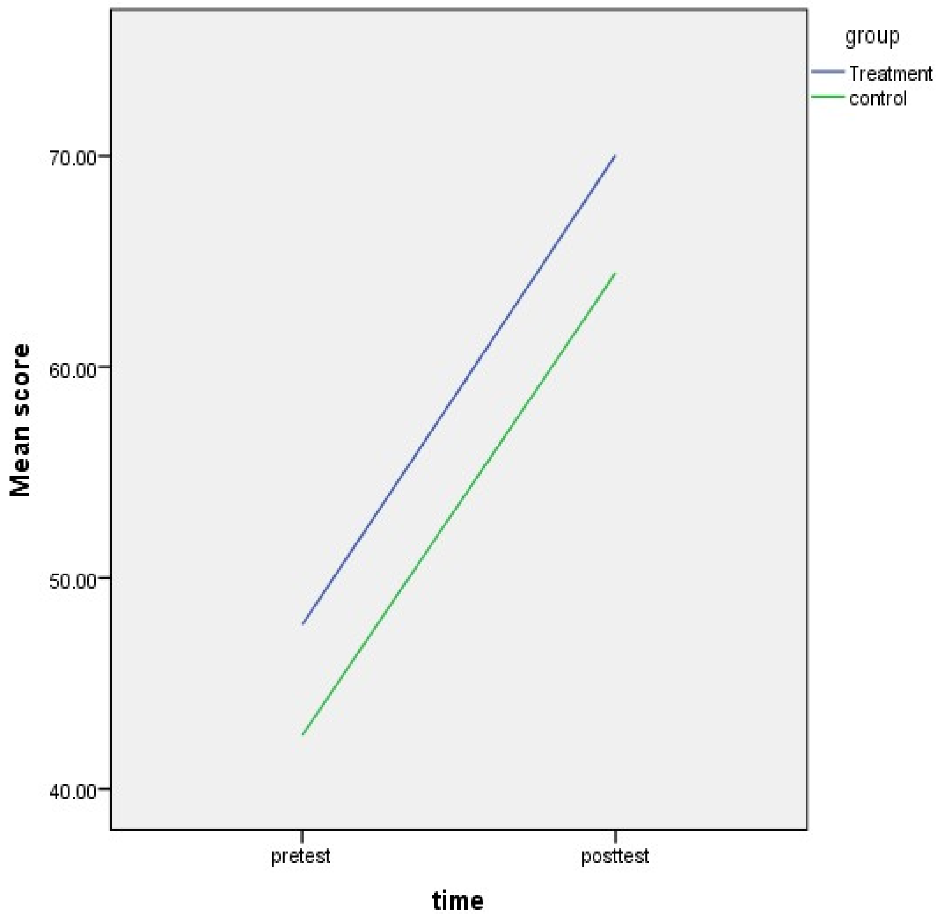

Figure 1. Graphical Progression of Treatment vs. Control for Duration of Study

Note: The treatment and control group mean scores progress virtually parallel over time.

Overall results indicated that both treatment and control groups increased as expected; however, the treatment group increased significantly, but only just. Finally, the researcher discovered that even with the statistical significance increase in posttest results, withholding the treatment from the control group students did not harm participant knowledge of electrophoresis concepts due to the time length in which the study was conducted.

Summary

This chapter described an exploration of the research findings by depicting the main purpose of the study, group descriptions, testing instrumentation, and an overview of the data. Significant results revealed by the ANCOVA measured the hypothesis and were discussed in relation to the research question. The final chapter will conclude this study with discussions and recommendations for future research in science education and teacher methodology.

Table 5 – FINDINGS, CONCLUSIONS, AND IMPLICATIONS

Introduction

The previous chapters portrayed a pretest-posttest analysis of a hands-on science study determined through knowledge of electrophoresis concepts. Moreover, this inquiry-based learning fostered the construction of the electrophoresis chamber, allowing students the chance to apply real-world knowledge diagnosing SCD before ascertaining statistical significance. The only descriptive elements considered were the six intact ninth-grade classes from the school schedule along with three accompanying biology teachers. This final chapter contains discussions from experimental results based upon theoretical and pedagogical models mentioned in previous sections and is categorized into five parts: (a) summary of the study, (b) findings, (c) conclusions, (d) implications, and (e) future research.

Summary of the Study

Smith (1992) deduced that knowledge is ascertained through student adaptation to the learning environment, which in turn incorporates constructed knowledge by the human capacity to learn from past experience. A contextual argument exemplified by Garbett (2011) demonstrated that discovery learning by students is a way to experience comprehension through past events; however, if the teacher is unable to be the causal factor, then a conceptual lack of understanding occurs. Reiber (1992) described these discovery-learning constructs where students make scientific correlations to the real world.

For science to be considered inquiry-based, students must investigate phenomena and explore variables rather than following an experimental guide. NISL (2012) standards required students to draw conclusions and apply deductive reasoning in order to identify a hands-on lesson as inquiry. When scientific exploration is derived by means of investigative techniques, students formulate hypotheses and infer real-world conclusions (MDE, 2012). This student-led discovery learning links phenomena studies and inquiry when the teacher is the educational guide facilitating the lesson (Maab & Artigue, 2013).

Scientific advancements, such as social media, wireless Internet, and medical innovation, continually drive the threshold of modern society. Consider technological innovations in medical practices applied toward DNA identification for solving crimes, stem-cell research, and disease classification techniques (Concheri et al., 2012). One such technique is known as “electrophoresis” which is the central focus of this study. Just like disease detection in a real-world medical laboratory, students constructed an electrophoresis chamber in order to reveal the presence of SCD in simulated blood samples. The CDC (2012) disclosed that 90,000 Americans of African descent have either Sickle-Cell trait or Sickle-Cell Anemia. When the hemoglobin in a blood sample is exposed to an electrical current through a medium, SCD is detected. There are previous studies providing evidence with a connection between electrophoresis concepts and inquiry learning. Data is lacking in the specific identification of SCD by means of inquiry learning whether or not knowledge of electrophoresis concepts will increase. This approach is distinctive due to participant construction and study of electrophoretic properties using inquiry-based methods.

The study was implemented at a public high school in South Mississippi and included approximately 150 ninth grade biology students. The students were part of six biology classes instructed by three different teachers. Three of the classes were treatment groups and three were control groups. Each instructor was highly regarded as teachers by school administration and were extremely interested in learning more about electrophoresis concepts in real-world scenarios. As an additional caveat, the teachers participated in a one-day professional development prior to carrying out the lessons with the intention of better understanding the concepts and chamber construction.

One research question was answered during this study. Will the use of a student-constructed electrophoresis chamber result in a statistically significant increase from pretest to posttest in student knowledge of electrophoresis concepts? The findings for this research question begin the next section.

Findings

Knowledge of Electrophoresis Concepts

The instrument used to measure knowledge of electrophoresis concepts or not was created through a collaborative effort between the researcher and participating biology teachers. Testing the content is the logical outcome of any teacher-made assessment. Hence, the verification of reliability and validity is pre-determined due to the content knowledge of the participants.

Summary Results of Knowledge of Electrophoresis Concepts by Time and Group

Will the use of a student-constructed electrophoresis chamber result in a statistically significant increase from pretest to posttest in student knowledge of electrophoresis concepts? According to results examined in chapter IV, there is a significant knowledge increase from pretest to posttest of electrophoresis concepts when students constructed the electrophoresis chamber. The key resultant measure of electrophoresis knowledge was indicated by the significant increase from pre- to posttest from group co-variant analysis. Similarly, a statistical analysis of time revealed a significant outcome; however, group versus time interactions unsuccessfully resulted in a significant effect even though knowledge in both treatment and control groups improved.

Conclusions for Knowledge of Electrophoresis Concepts

Group. Findings revealed a significant increase in electrophoresis knowledge when evaluating the treatment and control groups, even if only slightly significant. The noteworthy quantity is not that knowledge increased in both groups, but that knowledge in the treatment groups only increased slightly more. Based upon the predicted outcomes and previous research, the significant effects should have been much greater. This minimally significant result could be explained by the lack of basic science expertise (high school students), such as measuring volume making solutions or collecting quantitative and qualitative data. Wilke and Straits (2005) determined that students who display deficient skills are inhibited in performing inquiry-based laboratory techniques. This could possibly be the strongest indicator of such marginally significant results, which explains why students receiving the treatment did not improve statistically more compared to groups in which treatment was withheld. In fact, a further examination of the test items revealed more content questions from the PD material provided for the students to use during the presentation of information, rather than students constructing the chamber while learning about other electrophoretic properties. When Pascali et al. (2010) studied Lithium ion concentrations in bipolar disorder patients, electrophoretic techniques were employed to categorize the correct inorganic classifications. The migration patterns distinguish correct serum dosages. Therefore, increased electrophoresis knowledge greatly increased the effectiveness of the researchers' treatment. This further illuminates the idea that greater significant results may spring from students learning about actual scientific knowledge from the technological aspects of electrophoresis. This appears like common sense; yet, more students learning additional technical knowledge about all aspects of electrophoresis, not just disease identification, is substantial. This revelation entails a complete understanding of pedagogical inquiry-based knowledge grounded in theory to prevent misconceptions. When deficiencies are identified, the teacher must recognize where to apply corrective measures so that misconceptions about learning basic investigative procedures will not occur (Svinicki, 1991). Overall, it appears that students learning more in depth about basic laboratory techniques surrounding knowledge of electrophoresis concepts, science investigative procedures, and important technological aspects may bring about the greater statistically significant increase in knowledge originally predicted.

Time. As expected, there was a change in time as made obvious from the significant co-variant analysis. All students and teachers know and understand this. In fact, during the experiment itself, the researcher noted that participants verbally reported more time should have been spent on the teacher materials as well as constructing the chamber. Compared to previous studies and group v. time interactions described subsequently, time appears to play a greater role than previously predicted, whether results are significant or not. The researchers Garrison and Kanuka (2004) found that when studying the combining of technology with a hands-on approach to learning science, academic achievement increased only when more time was allowed for supplemental investigative techniques. This important caveat with regard to time was of note due to rigor as an important quantity included in an experiment. The addition of rigor caused the experiment to last longer; therefore, the potential gain in knowledge overshadowed the added time any experiment takes to increase inquiry learning and student achievement. Consider the effect time had on children when Morf (1997) described individuals interacting with their environment learning through first-hand experiences. The passage of time cognitively generates the ability to make future decisions with past experience from which to draw upon. As the lifespan of the child continues, additional constructive decisions occur. As any epiphany where research brings forth unexpected results, the highly significant time co-variation plainly demonstrates that no matter the level of experimental complexity, time must be allowed in order to achieve desired outcomes.

Time v. Group Interactions. Commonly found within many different electrophoretic detection methods in medical research, treatment group participants on the whole tend to exhibit both significant and no significant effects. This is consistent with the findings of Turkez et al. (2011) when toxicity levels were tested using electrophoresis detection by mixing human blood samples with common household oral care products. The results were not significant; however, knowledge still increased even without significant results. Each product generated results adding noteworthy data. This illustrates the importance of learned information through research even when outcomes do not match predictions. Results of this study through group v. time interactions were not significant. However, a closer examination revealed that both control and treatment groups increased in knowledge. This indicates that even though the control groups did not receive the treatment, knowledge was gained and no harm was imparted to the control groups when treatment was withheld. This further supports the notion for investigating interactions between groups over time periods of sufficient length to provide likelihood of significant results.

There is more support for the notion of conducting studies and gaining important knowledge over a given time period even without statistical significance in keeping with doing no harm. Odunvbun et al. (2008) recruited over 600 expectant mothers to conduct SCD screenings, and essential results were discovered. The results were not significant from a statistical standpoint; yet a small percentage of the infants tested positive for SCD. One can be sure that the participants were not concerned with the scientific knowledge of the study, only the realization about their offspring to receive as early treatment as possible for SCD. Conversely, a study by Rahimi et al. (2006) examined the genetic mutations of nomadic tribes from Iran with a history of SCD. A common genetic indicator was identified and traced back hundreds of years. By comparing this genetic marker among several other tribes in the region, the researchers were able to produce significant results by ascertaining the cause of SCD within the tribe. The findings are consistent with the researcher's conclusion from this study that group v. time interactions were not significant due to the amount of time allowed during the study for knowledge to increase.

Implications

In order for students to effectively learn science concepts through inquiry, three significant topics must be incorporated within institutions where students learn scientific concepts: professional development for science teachers and candidates emphasizing rudimentary laboratory methods, laboratory work focusing on investigating a phenomenon, and student activities making authentic, real-world connections.

Emphasizing Rudimentary Laboratory Methods

Before students can benefit from discovering all the important concepts available during hands-on experimentation, fundamental laboratory skills must be acquired. The researcher discovered during the study that most students lacked not only simple measuring skills, but also knowledge regarding the fundamental use of basic laboratory instrumentation, such as pipetting liquids, measuring lengths, or weighing chemicals. So much of the Mississippi science framework highlights these topics that most are described under a separate content strand, which is intended to be included throughout the other's content (MDE, 2010). As early as kindergarten, students are expected to demonstrate an investigation, compare size and shape of objects, and recognize laboratory instruments such as thermometers and scales. In fact, there is a requirement at each grade-level throughout a student's science education with differences incorporating progressive depth of knowledge. This detail is significant. If scientific investigation through inquiry learning is the course to which the educational community is to navigate, then all students and science teachers must be trained in not only what, but how to appropriately employ scientific and investigative techniques. This is consistent with Gott and Duggan's (1995) examinations into the significance toward establishing knowledge of facts and procedures as a requirement for inquiry learning. This also suggests that teachers must be provided with professional development during preservice years, as well as throughout their careers. This point was abundantly clear during the one-day professional development session the researcher conducted for the teachers implementing this study. The researcher noted an inherent lack of rudimentary skills each teacher demonstrated at varied aptitudes. Knowledge of science concepts was evident; however, practical laboratory abilities were lacking. Therefore, teachers must also embrace this implication toward laboratory techniques before the students will. As more students experience incorporating rudimentary laboratory methods into a typical science lesson, the knowledge will become second nature, allowing for an essential understanding of all scientific research.

Investigating a Phenomenon

Expanding upon the first implication, inquiry is not simply a hands-on experiment to where methodical steps are followed which lead students to a spectacular discovery that is merely fun to complete. When the MDE (2012) incorporated inquiry as a fourth content strand, the aim was to stimulate problem-solving and investigative skills. In many experiments, students and teachers become fascinated with a color change, mixing solutions together, or an explosion, which is then misconceived as a good science lesson. However, the emphasis must be toward investigating a phenomenon. Therefore, any inquiry-based lesson must be grounded in drawing conclusions by gathering data from a thorough exploration of phenomena (NISL, 2012). Even in a demonstration described by Hunter (1994) as the hook or focus which captures student interest to introduce a lesson, the significance is lost if the important scientific concept is not emphasized. In order for a teacher to truly take a lesson to the next level toward inquiry, then all aspects of a scientific investigation must be encapsulated. Sandoval and Morrison (2003) addressed research as something needing to overtly illustrate the exploration of phenomenon. Students need science to be interactive or risk the topic being reduced to a novelty not taken seriously and soon forgotten when the lesson concludes.

Authentic, Real-World Connections

Students learn more efficiently when a topic is understood within a contextual framework. Simply following steps in a lab manual, as many science classrooms are conducted, may lead to insufficient opportunity for making the proper connection to something familiar in which a student can associate. The proper way is to make science interesting and persistently habitual toward establishing real-world connections as commonplace. One only has to examine data from this study where both treatment and control groups increased knowledge for support from this revelation. The very nature of the experiment linking a detection method to SCD immediately caught the attention of several participants. Many revealed knowledge of SCD due to having a close relative with the disease. In fact, the researcher became aware of more than one participant with the disease itself. Herron, Parr, Davis, and Nelson (2010) realized during a study with high school biology teachers reacting positively toward learning how to make science authentic to students by means of studying SCD. The investigation revealed how receptive the participants were to learn about applying SCD in their biology classrooms due to the familiarization many students have with the disease. Using one's own environment as a basis from which to learn or explore brings forth the means to activate prior knowledge. Such learning platforms allow students to research subjects, refine knowledge, and discover themes (Cobb et al., 1992). An advocate for students conducting real-world investigations, Fosnot (1996) expressed how students must be allowed to ascertain information through cognitive thinking, which eventually produces engaging activities. Fosnot's (1996) viewpoint was to learn by active engagement. What better way for students to explore science concepts than something as real or authentic as SCD was to several of the participants in this study?

Future Research

This knowledge of electrophoresis research study revealed an increase of conceptual understanding across two distinctive groups. Both groups suggested knowledge increases; so, results supported the predicted significant outcomes, even if results were only of minor consequence. This means that students building their own chambers had little effect on the results; therefore, regardless of how noteworthy the experiment is around the subject studied, more time must be allowed to obtain statistically significant results of any distinction.

Differing Disease and Detection Methods over Time

If education stakeholders truly want to make a difference resulting in significant gains of student knowledge, then hands-on experiments must take a longer time period. Over the course of an entire semester, more research is needed studying students learning multiple hands-on, inquiry-based techniques beyond electrophoresis when testing for SCD or any other science topic. Investigations are needed here. Teachers demonstrate many science topics using multiple hands-on devices over a nine-week period or semester. The control groups only get lectures, and the treatment groups build the devices. The type of hands-on device is up to the educator. The results of this study vividly articulated that experimenting with differing hands-on devices used for detecting SCD might increase the likelihood of significant results. Researchers could also choose another disease as the test subject. Contrary to various hands-on methods over extended time periods, one can visualize how a slight deviation could incorporate learned electrophoretic methods while testing detection methods of multiple diseases. This could enhance knowledge even further if students are forced to adapt to the changing data by truly studying and predicting outcomes. In fact, one would expect students to become experts themselves after learning to adapt their constructed devices and testing them on such a wide variety of subjects and altered methods. Such a study would embrace each perspective from a hands-on standpoint deciphering significant correlations of many common diseases using electrophoretic or other forensic detection methods, thereby producing unique amounts of variant and co-variant analysis from which to interpret.

Improved Measurement Tool with Increased Participation

Since the findings indicated negligible significance from pretest to posttest in knowledge of electrophoresis concepts, the researcher suggests the study be repeated with an improved tool for measuring content knowledge. The content valid test itself measured what was taught; however, too much emphasis was placed on the lesson format and presentation rather than the hands-on portion. Broadening input from a panel of experts outside of the science educational realm would increase the content knowledge the test was already intended to measure. Why not consult forensic specialists or biochemists for input toward improving the best possible measure of knowledge from an expert's chosen field of study? In other words, future research using such a tool for measuring knowledge of electrophoresis concepts could best be served by including stakeholders of electrophoresis other than just science teachers.

Finally, the participants from this study centered around students from six intact classrooms in one high school. A broader view comparing the results from multiple high schools from across the local area, state, or even randomly from across the country would provide a much larger view in which to increase knowledge of electrophoretic or other science concepts.

APPENDIX A – Fidelity Observation Checklist: Building the Electrophoresis Chamber

FIDELITY OBSERVATION CHECKLIST: BUILDING THE ELECTROPHORESIS CHAMBER

* Period

* Date

* Duration

* Instructor (name or letter)

Rater #1 Rater #2

* What type of group is being observed?

- Treatment
- Control

Items below marked, "***Yes***" indicate that the observer witnessed the step taught by instructor or that students completed step due to instructor's direction.

* Please choose the best answer for each of the following.

	[redacted]	[redacted]	[redacted]
Overview of components discussed: household products compared to commercial product			
Commercial electrophoresis uses were discussed			
Solutions were prepared or demonstrated			
Electrode pathway prepared			
Platform established (if applicable)			
Power supply constructed using diagram (test if applicable)			
Electrodes inserted and explained			

APPENDIX B – Treatment Group Lesson Plan

TREATMENT GROUP LESSON PLAN

<table>
<tr><td colspan="2">Objective
INQUIRY
1. Apply inquiry-based and problem-solving processes and skills to scientific investigations.
e. Analyze procedures, data, and conclusions to determine the scientific validity of research. (DOK 3)
f. Recognize and analyze alternative explanations for experimental results and to make predictions based on observations and prior knowledge. (DOK 3)

LIFE SCIENCE
5. Demonstrate an understanding of the molecular basis of heredity.
c. Examine inheritance patterns using current technology (e.g., pedigrees, karyotypes, gel electrophoresis). (DOK 2)</td></tr>
<tr><td>WOW (Check Box)
o Content and Substance
o Organization of Knowledge
o Product Focus
o Clear and Compelling Standards
o Protection from Adverse Consequences of Initial Failures
o Affirmation
o Affiliation
o Authenticity
o Novelty and Variety
o Choice</td><td>Academic Vocabulary/Terms

See electrophoresis slides</td></tr>
<tr><td colspan="2">Bell ringer (5-7 minutes)

SATP questions 11-14 (Genetic mutations not part of the experiment); ACT review questions of the day (not part of the experiment), Pretest</td></tr>
<tr><td colspan="2">Introduction/Anticipatory Set (Set/Hook/Focus) (3 -5 minutes)

Except for day one with the Pretest, each day will consist of a short review of previous day's activity regarding electrophoresis: YouTube video, pictures, and review of electrophoresis graphic organizers.
See electrophoresis slides</td></tr>
<tr><td colspan="2"></td></tr>
</table>

Table A1. – Control Group Lesson Plan

CONTROL GROUP LESSON PLAN

<table>
<tr><td colspan="2">Objective
INQUIRY
1. Apply inquiry-based and problem-solving processes and skills to scientific investigations.
e. Analyze procedures, data, and conclusions to determine the scientific validity of research. (DOK 3)
f. Recognize and analyze alternative explanations for experimental results and to make predictions based on observations and prior knowledge. (DOK 3)

LIFE SCIENCE
5. Demonstrate an understanding of the molecular basis of heredity.
c. Examine inheritance patterns using current technology (e.g., pedigrees, karyotypes, <u>gel electrophoresis</u>). (DOK 2)

NOTE: The control group activities should not take the entire week. Once the research activities are completed, the class will continue on with previously planned curriculum in preparation toward final exams.</td></tr>
<tr><td>WOW (Check Box)
o <u>Content and Substance</u>
o Organization of Knowledge
o Product Focus
o Clear and Compelling Standards
o Protection from Adverse Consequences of Initial Failures
o Affirmation
o Affiliation
o <u>Authenticity</u>
o Novelty and Variety
o Choice</td><td>Academic Vocabulary/Terms

See electrophoresis slides</td></tr>
<tr><td colspan="2">Bell ringer (5-7 minutes)

SATP questions 11-14 (Genetic mutations not part of the experiment); ACT review questions of the day (not part of the experiment), Pretest</td></tr>
<tr><td colspan="2">Introduction/Anticipatory Set (Set/Hook/Focus) (3 -5 minutes)

Except for day one with the Pretest, each day will consist of a short review of previous day's activity regarding electrophoresis: YouTube video, pictures, and review of</td></tr>
</table>

!INSTRUCTOR SLIDES!

Got Electrophoresis?

Sickle-Cell Anemia

Parker M. Nelson, M.Ed.

STUDENT SLIDES

Got Electrophoresis?

Sickle-Cell Anemia

Parker M. Nelson, M.Ed.

APPENDIX E – Lab Instructions

LAB INSTRUCTIONS

Got Electrophoresis?

Sickle-Cell Anemia

An Easy, Low-Cost Method that Simulates the Identification of Sickle-Cell Anemia by Means of a Student-Made Electrophoresis Chamber.

Presenters: Parker M. Nelson M.Ed.

APPENDIX F – Electrophoresis Concepts Assessment

ELECTROPHORESIS CONCEPTS ASSESSMENT

1. What is the charge of normal hemoglobin?
a. positive b. negative c. neutral

2. Which disease was first to be studied with electrophoresis?
a. HIV/AIDS b. Syphilis c. Sickle Cell Disease d. Typhoid Fever

3. Which answer best describes how Sickle-Cell is identified by electrophoresis?
a. how far the bands move b. color changes in the bands c. shape of the bands

4. Toward which electrode do hemoglobin molecules move during electrophoresis ?
a. anode b. cathode c. anion d. cation

5. During electrophoresis, which hemoglobin sample will move the longest distance?
a. Sickle Cell Trait b. Sickle Cell Disease c. Normal

6. Screening for Sickle Cell Disease is conducted with
a. electrophoresis b. cultured bacteria c. live mice

7. What are the millions of molecules that are found in red blood cells called?
a. fat b. urine c. DNA d. hemoglobin

8. What happens to red blood cells during a Sickle Cell crisis?
a. explode b. change shape and become sticky c. fall apart d. shrivel up

9. What are the symptoms of a Sickle Cell crisis?
a. blood clots b. stroke c. pain d. all of these

10. Which phrase best describes a blood sample with Sickle Cell Trait?
a. bone marrow transplant b. contains ½ normal and ½ sickle hemoglobin
c. contains all sickle hemoglobin d. contains all normal hemoglobin

11. What substance does hemoglobin transport throughout the body?
a. oxygen b. urine c. sugar d. fat

12. What does electrophoresis do to organic molecules?
a. condenses them b. chemically combines them
c. separates them d. causes them to fall out of solution

APPENDIX G – IRB Approval Letter

THE UNIVERSITY OF
SOUTHERN MISSISSIPPI

INSTITUTIONAL REVIEW BOARD
118 College Drive #5147 | Hattiesburg, MS 39406-0001
Phone: 601.266.5997 | Fax: 601.266.4377 | www.usm.edu/research/institutional.review.board

NOTICE OF COMMITTEE ACTION

The project has been reviewed by The University of Southern Mississippi Institutional Review Board in accordance with Federal Drug Administration regulations (21 CFR 26, 111), Department of Health and Human Services (45 CFR Part 46), and university guidelines to ensure adherence to the following criteria:

- The risks to subjects are minimized.
- The risks to subjects are reasonable in relation to the anticipated benefits.
- The selection of subjects is equitable.
- Informed consent is adequate and appropriately documented.
- Where appropriate, the research plan makes adequate provisions for monitoring the data collected to ensure the safety of the subjects.
- Where appropriate, there are adequate provisions to protect the privacy of subjects and to maintain the confidentiality of all data.
- Appropriate additional safeguards have been included to protect vulnerable subjects.
- Any unanticipated, serious, or continuing problems encountered regarding risks to subjects must be reported immediately, but not later than 10 days following the event. This should be reported to the IRB Office via the “Adverse Effect Report Form”.
- If approved, the maximum period of approval is limited to twelve months.
  Projects that exceed this period must submit an application for renewal or continuation.

PROTOCOL NUMBER: 12050101
PROJECT TITLE: Will the use of a student-constructed electrophoresis chamber result in a statistically significant increase from pretest to post test in student knowledge of electrophoresis concepts?
PROJECT TYPE: New Project
RESEARCHER(S): Parker M. Nelson
COLLEGE/DIVISION: College of Education and Psychology
DEPARTMENT: Curriculum, Instruction and Special Education
FUNDING AGENCY/SPONSOR: N/A
IRB COMMITTEE ACTION: Exempt Approval
PERIOD OF APPROVAL: 05/01/2012 to 04/30/2013
Lawrence A. Hosman, Ph.D.
Institutional Review Board

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