Fall 10-2016

Action Research Using Entomological Research to Promote Hands-On Science Inquiry in a High-Poverty, Midwest Urban High School

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by

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A Dissertation submitted to the Education Faculty of Lindenwood University

in partial fulfillment of the requirements for the

degree of

Doctor of Education

School of Education

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This dissertation has been approved in partial fulfillment of the requirements for the degree of

Doctor of Education

at Lindenwood University by the School of Education

Dr. John Long, Dissertation Chair	10.14.16 Date
Dr. Graham Weir, Committee Member	10/14/16 Date
Dr. Charles Brazeale, Committee Member	10-14-16 Date

Declaration of Originality

I do hereby declare and attest to the fact that this was an original study based solely upon my own scholarly work here at Lindenwood University and that I have not submitted it for any other college or university course or degree here or elsewhere.

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Signature: Dustin Stockmann Date: 10/14/16

Acknowledgements

Many individuals have helped me to complete this dissertation. Chief among them is Dr. John Long, my dissertation chair, who helped me push my way through this process. I also wish to express heartfelt thanks to two committee members, Dr. Graham Weir, and Dr. Charles Brazeale, for their focused assistance.

In addition, I thank the study's participants, the cooperating school, and its administrators for making possible the completion of this research in their district.

Finally, I acknowledge my family members for their unwavering support, encouragement, and understanding throughout this entire project. Thank you Debbie, Florene, Denise, David, and Kalyn for enabling me to complete my academic journey.

Abstract

The purpose of this mixed-methods action research study was to examine to what extent entomological research can promote students' hands-on learning in a high-poverty, urban, secondary setting.

In reviewing the literature, the researcher was not able to find a specific study that investigated how entomological research could promote the hands-on learning of students. The researcher did find evidence that research on learning in a secondary setting was important to student growth. It should also be noted that support was established for the implementation of hands-on science inquiry in the classroom setting.

The study's purpose was to aid educators in their instruction by combining research-based strategies and hands-on science inquiry. The surveys asked 30 students to rate their understanding of three basic ideas. These core ideas were entomological research, hands-on science inquiry, and urban studies. These core ideas provided the foundation for the study. The questionnaires were based on follow-up ideas from the surveys. Two interview sessions were used to facilitate this one-on-one focus.

Because the study included only 30 student participants, its findings may not be totally replicable. Further study investigating the links between entomological research and hands-on science learning in an urban environment is needed.

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Chapter One

Overview of the Study

Science subtly impacts every facet of life for every individual (McComas, Clough, & Almazroa, 2002). When science becomes observable for the average individual, the lack of science understanding becomes potentially harmful. Skinner (1968) said, “Scientists have not brought methods of science to bear on the improvement of instruction” (p. 740). A limited number of high school students go on to college with an interest in any of the scientific fields because of a lack of exposure to an experienced science teacher (Skinner, 1968).

Next Generation Science Standards (NGSS) encouraged school-aged children to engage in the formation of actual, accurate concept models, central to an understanding of scientific fields of study (Next Generation Science Standards [NGSS], 2013b). These standards, as described by Cartier, Rudolph, and Stewart (2001) explained that scientific models are “sets of ideas that describe a natural process” (p. 2). These models could take many forms, representing a range of ideas from inquiry, to problem-based learning, to hands-on learning (Stepien & Gallagher, 1993).

A background knowledge of science literacy gave individuals a better understanding of the world around them (National Research Council, 1996). An understanding of science also aided in the creation of new ideas that influenced student achievement in general science (Zhang, 2008). Research on science educators’ training had revealed that most school-age students retained information best by hands-on experiences (Golick, Heng-Moss, & Ellis, 2010).

This study reported in this dissertation examined how hands-on science could potentially be promoted to high school students promoted by using entomological research in a high-poverty urban setting, with students in a Midwest school district. The term "hands-on science," as explained by Ruby (2001) included, "all hands-on activities carried out by students during a science class" (p. 7). Hands-on science education was a method increasingly in use since the 1970s (Ingison, 1978). Some educators and scientists questioned whether hands-on science instruction was the correct method for teaching science and whether it supported the goals of science education (Ruby, 2001).

Background of the Problem

'Hands-on learning' was an expression in science-educator training that signified various tools used to teach students how to learn concepts (Haury & Rillero 1994). At the time of Haury and Rillero's (1994) writings, many ideas circulated about what constituted the foundation of hands-on learning in a science classroom. Assembling different viewpoints from educators, curriculum coordinators, and other members of educational organizations, Haury and Rillero (1994) arrived at a consensus of what learning by using hands-on activities in science meant. Hands-on learning in high school science courses must involve either an individual, or a group of individuals, working with physical objects to gain either knowledge, understanding, or both together during the activity (McIntyre, 2015). Significant attention was devoted to science in the American school system since the 1860s (Skinner, 1968). Nevertheless, the common understanding of 'hands-on,' or activity-based learning, emerged during the 1960s. A literature review showed that there was a debate over hands-on learning in science education and how new initiatives affected implementation in schools (as cited in Ruby, 2001).

Statement of the Problem

Ruby (2001) described hands-on science as “a means to increase science achievement in science education” (p. 27). A crucial aspect of the hands-on science model was how management of the “equipment, materials, movement of people, and space is handled” (Froyen & Iverson, 1998, p. 128). Research on the effectiveness of a hands-on approach to science education continued to grow over the years, previous to this study (Stohr-Hunt, 1996). Some researchers claimed that this type of activity was extraordinarily successful in classrooms, while others showed that the method was not always the best one to use (National Center for Education Statistics, 1989). Given such divergent views, this study sought to investigate how use of hands-on science experiences could potentially improve, by examining the use of entomological research. It specifically looked at the effects of entomological study on students in a high-poverty urban setting.

Importance of the Study

This study examined how science instruction could possibly be improved by using entomological research to promoted hands-on science inquiry in a high-poverty urban setting, with secondary students in the Midwest.

A literature review showed a clear relationship between hands-on learning and entomological research (Ruby, 2001). The literature review did not indicate any previous connection between entomological research and a high-poverty urban setting. There was, however, research connecting hands-on learning in such a high poverty urban environment. This study investigated various factors of the hands-on model of science teaching. It also elaborated upon how use of entomological research could demonstrate hands-on science teaching.

Purpose of the Study

This action research study investigated whether using entomological research to promote hands-on science inquiry increased student-reported comfort with science. The researcher utilized an online survey of secondary students from a high-poverty urban setting in the Midwest. Participants of the investigative study scored responses, working with a Likert scale, for statements concerning how they felt about using insects in a science class. Participants answered open-ended questions related to the online survey statements. Figure 1 shows the relationships between the different aspects of the research, which included the hands-on model, science inquiry, entomological research, and science literacy.

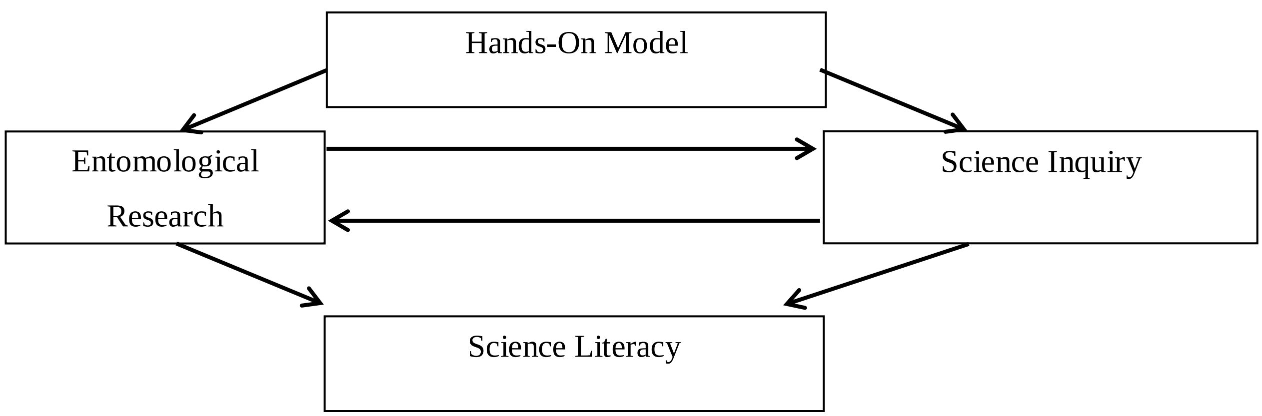

Figure 1. Relationships between research elements for study.

Hypotheses and Research Questions

H1a: Following participation in the hands-on entomological research science unit, students will exhibit a difference in understanding of science concepts, measured by a comparison of pre-to-post Survey Questions (# 3, 5, 8, and 9).

H2a: Following participation in the hands-on entomological research science unit, students will exhibit a difference in perceptions and attitudes concerning science, measured by a comparison of pre-to-post Survey Questions (# 1, 2, 3, 4, 6, 7), and 10.

RQ 1: How does hands-on science affect students' perspective on learning?

RQ 2: How does hands-on science affect students' understanding of concepts?

RQ 3: How can using research in a science class improve hands-on education?

RQ 4: How does using entomological research contribute to improving science education?

RQ 5: How can entomological research improve high-poverty students' learning science?

Variables

The independent variable in this investigative study was the use of entomological research, in conjunction with the hands-on science model. The dependent variable was how effective the hands-on model of learning was on student comfort level, when implemented with entomological studies.

Limitations of the Study

"When a study has internal validity, it means that any relationship observed between two or more variables should be unambiguous as to what it means rather than being due to 'something else'" (Fraenkel, Wallen, & Hyun 2012, p. 166). The students included in the study were all from a high-poverty urban setting in a Midwest secondary school. Because all the participants were minors, letters were required indicating parental permission and student willingness to participate in the study. The additional step of requiring parental consent may have inadvertently excluded some participants, whose contribution may have changed the outcome of this study.

Collecting data in the form of a survey questionnaire and of a questionnaire was also a limitation, due students' abilities to comprehend what the questions were specifically asking. Another limitation of this research study was that the researcher had to limit his contact with the participants, because of his role as a teacher in the urban school setting at the site of the research.

Definition of Terms

Action research: "Instead of searching for robust generalizations, action researchers (often teachers or other researchers) focus on obtaining information that will enable them to change conditions in a particular situation in which they are personally involved" (Fraenkel et al., 2012, p. 14).

Content standards: Statements of significant concepts and generalizations in a particular content area (Marzano, Pickering, & McTighe, 1993).

Cooperative learning: An instructional method used, which directed students to work together in small groups to promote learning (Slavin, 1995).

Entomological research: Fundamental or basic research on insects as the organisms under study (Gillott, 1985).

Entomologists: People who study insects (University of California, 2015).

Entomology: The study of insects (University of California, 2015).

Hands-on learning: A total learning experience involving critical thinking by completing a plan and a process. In this process an individual can obtain and explain results (Haury & Rillero, 1994).

High-poverty students: Students who applied for, and were eligible for, the federally sponsored free and reduced-cost lunch program because their families' incomes fell below the set poverty line (Clotfelter, Ladd, Vigdor, & Wheeler, 2007).

Insects: Organisms whose characteristic features are a hard, jointed exoskeleton and segments called the head, thorax, and abdomen (Chapman, 1998).

Instructor: An individual who plays an integral role in the development of a constructivist-learning environment (Johnson & Renner, 2012).

Next Generation Science Standards: This model incorporated science into K-12 education. It also connected engineering, in a broad sense, to cover achievement in solving problems that were natural and man-made ((NGSS, 2013a).

Project-Based Inquiry Science: A platform of science created by using differentiated tasks in a project-based format (Kolodner, Zahm, & Demery, 2015).

Student Learning Outcomes: Statements defining significant and essential learning students have achieved and that can be demonstrated at the end of a course or program. Learning outcomes determine what a student will know and be able to do by the end of a course or program (Lesch, 1995).

Student self-assessment: A tool that students use to develop understanding of a topic (Marzano et al., 1993).

Urban school setting: A school located in an urban, rather than rural, small-town, or suburban setting. The school's setting often has a high rate of poverty as calculated by free and reduced-cost lunch data. It often has a significant proportion of students of color or first-generation ethnic background (Russo, 2004).

Urban students: Children from a lower socioeconomic status with high mobility and strongly influenced by their race/ethnic background (Raskin, Stewart, & Haar, 2012).

Summary

Chapter One introduced the educational background for how this investigative study added to the then-current body of educational knowledge, regarding hands-on science education at the secondary level. This study was designed to determine how entomological research could promote hands-on science learning. Research indicated that students in a high-poverty school setting, who had the opportunity to conduct hands-on science, typically performed better at tasks in science classes. Research also indicated that students who incorporated research-based tasks into the learning environment had a vastly vocabulary of technical terms at their disposal. Chapter One also defined the study's purpose and explained the research questions to be answered. Chapter Two investigates the literature related to the topic of hands-on science and entomological research. The literature review focuses on the areas of action research, high poverty, hands-on learning, urban school settings, and urban students.

Chapter Two: Review of the Literature

Introduction

Chapter Two reviews the scholarly literature pertaining to the action research project described and reported in this document. It begins with a review of the research modality and moves through components that separate this study from others. These components include entomological research, hands-on learning, and cooperative learning. The researcher also discusses factors important to the setting, such as urban education and poverty.

Action Research

Action research in education was a systematic practice that engaged a single teacher, a group of individuals who shared a common goal, or an entire faculty at a school or in a district (Sagor, 2000). Action research was also a method of organized inquiry that searched for ways to advance social concerns affecting the lives of individuals in many different locations (Hine, 2013). Historically, the expression 'action research' attributed to the work of Lewin, who considered this research technique in education as collaborative, recurring, and powerful (as cited in McNiff & Whitehead, 2010). Through replicated rounds of outlining, observing, and pondering, people engrossed in action research carried out changes required for collective advancement (McNiff & Whitehead, 2010).

Along the same lines, Kemmis, McTaggart, and Nixon (2014) regarded action research as collaboration in creating a process that shared data and information. Action research described reflective inquiry to improve the practice of colleagues in a communal environment. This setting created opportunities to advance a social or educational process. It related to the sensitivity of the practices and the environment in which they were completed (Kemmis, McTaggart, & Nixon, 2014). Action research sought down-to-earth explanations with respect to different topics of compelling concern to individuals and to a populace as a whole (Hine, 2013).

Cooperative Learning

Many different teaching styles in the classroom were available to enhance student learning. Two approaches were fundamental to cooperative learning. The first strategy involved genuine independence and individual responsibility (Hassard, 2011). The second strategy was positive interdependence in smaller groups. Students engaged in cooperative learning were more successful in solving four types of problems: linguistic, nonlinguistic, well-defined, and ill-defined problems (Hattie, 2009).

Students who participated in cooperative learning worked collaboratively to master subject matter. Groups varied in size from two students to several. Individual students typically had specific jobs or responsibilities while completing an assignment. Teachers graded these clusters of students on the group's performance or a calculated average of a member's performance within the group (Slavin, 2010).

Cooperative learning was practiced in all academic subjects, by students of all ages, and in all types of schools across the world (Hattie, 2009). There were four major dimensions of cooperative learning and its relationship to achievement: motivational, social cohesion, cognitive awareness, and structured group interaction (Slavin, 2010).

Entomology

Entomology was the study of insects (Turpin, 1992). Another term that could be used was the term hexapod, which had its basis on the Greek wording of *hex*, that meant six and *podos* that meant foot. Insects were the dominant group of animals on the surface of the Earth and in the freshwater of the world. There were over a million species of insects identified and cataloged. These insects played a role in balancing nature, as well as providing a beginning food source for most animals.

Humans spend their intellectual energies in three basic areas of activity: surviving, using practical learning (the application of technology); seeking pure knowledge through inductive mental processes (science); and pursuing enlightenment to pleasure in aesthetic exercises that may be referred to as the 'humanities' (Hogue, 2003). Entomology was concerned with survival (economic or applied entomology) and scientific study (academic entomology), but the branch of investigation that addressed the influence of insects (and other terrestrial Arthropoda, including arachnids and myriapods, etc.) in literature, language, music, the arts, interpretive history, religion, and recreation was only recognized as a distinct field recent to Hogue's (1987) writings. This was referred to as 'cultural entomology' (Hogue, 1987).

Because the term 'cultural' was narrowly defined, some aspects normally included in studies of human societies were excluded. Thus *ethnoentomology*, concerned with all forms of insect-human interactions in so-called primitive societies, was not synonymous with cultural entomology (Hogue, 1980). For this reason, *entomophagy*, as practiced to complete the regular diet of an Indian tribe, was applied entomology and not covered in the literature. However, entomophagy occurred for recreation or ceremonial reasons (Hogue 1985). Likewise, pharmacological, manufacturing, or other wholly practical uses of insects, even though unusual, such as applications in forensic science, were not part of the subject. The narrative history of the science of entomology was not part of cultural entomology, while the influence of insects on general history was considered cultural entomology (Clousdsey-Thompson, 1976).

Insects assumed a position of unusual significance for certain ethnic groups or nations. To the ancient Egyptians and neighboring cultures, various insects were revered; in particular, several species of dung scarab (*Phaeniini, Coprini*) rose in religious and symbolic importance early in history (Kritzky & Cherry, 2000). This was witnessed by the prevalence and persistence (approximately 2200 BC to New Kingdom times, circa 1000 BC and later) of scarab imagery in worship and funeral ceremony (Kritzky & Cherry, 2000).

The Japanese developed a tradition of aesthetic appreciation for insects, reflected in their literature, art, and recreational pursuits. This attracted some sensitive commentary by a few authors, such as Hearn and Kevan (as cited by Laurent, 2000). Much of the same could be said of the Chinese, who held crickets and other musical *Orthoptera* in particularly high esteem (Laurent, 2000).

Few authors treated the subject of cultural entomology in general terms. Literature was sparse and not referenced to this subject in bibliographies. Information was often oriented geographically or included in extra-disciplinary works, especially works on history, iconography, classics, and anthropology. Because cultural aspects often intersected other insect-related topics, examples were sometimes found within literature dealing with entomological history, the entomological impact on human welfare, or taxonomy of specific groups (Berenbaum, 1995).

The subject was popular with entomologists from around the world. A directory of investigators listed almost 70 people (1987). The first colloquium on cultural entomology took place at the 17th International Congress of Entomology in Hamburg in 1984. Participants created a list of the fields of study comprising the subject (Hogue 1985). Although some overlap occurred, these topics listed were used as an outline for the following discussion.

Literature and Language

Insects appear frequently in literature. Hogue (1987) recorded there were approximately 100 titles of modern novels, and almost as many short stories in English, with fictional plots in which insects had a major role. Insects were useful for establishing a variety of moods or images, both negative (more usual) or favorable. Among the former were many legitimately injurious or dangerous qualities, such as the ability to entrap in *Woman in the Dunes*, by Abé (1964); poisonous stings in *The Furies*, by Roberts (1966); rapaciousness in *Bugged*, by Glut (1974); and swarming instinct in *The Swarm*, by Hertzog (2002). Thus, they provided foundations for many tales of fantasy, such as, *Leinigen versus the Ants*, by Stephenson (1938); and intrigue The *Gold Bug*, by Poe (1843); but were most abundant in science fiction, either as conjured earthly villains *Bugs*, by Roszak (2003) or space monsters *Bug Wars*, by Asprin (1979). Because they were capable of delivering lethal toxins, some species were employed as murder weapons in detective novels; as in the honeybee in *A Taste for Honey*, by Heard (1964). Others with intimate microhabitats acted as voyeurs and relate erotic tales, such as, *The Fly*, by Chopping (1966); *Autobiography of a Flea*, by Anonymous (1887). Several stories played on the metamorphosis theme, with humans assuming insect characteristics to a limited degree, as in *Spider Girl*, by Lear (1980); or consuming degree, as in *Metamorphosis*, by Kafka (1915) (as cited in Hogue, 2003).

Positive attributes ascribed to insects and spiders, such as patience or industriousness, was the basis for a variety of proverbs and parables; this was true of several among Aesop's (620-560 B.C.E.) *Fables* (e.g. against arrogance: "A fly sitting on a chariot wheel said, 'What a dust I raise!'" (Whitney & Smith, 1914, p. 307). Some insects with especially likable traits, such as musical talent Jiminy Cricket, *grigs* (an old term for *orthopteroid* insects, revived by Kevan), or high intelligence for Archy, the cockroach, in the *Lives and Times of Arch and Mehatibel*, by Marquis (1927), become famous literary figures. A cute, rotund form speaks a message of friendliness and good humor, and little round beetles, bumblebees, woolly caterpillars, and fat spiders were insect friends in *Charlotte's Web* by White (1952) (as cited in Berenbaum, 2000).

Parallels between human and insect societies provided a foundation for interplay between two life forms in *Consider Her Ways*, by Grove (2001). The size disparity problem was solved either by magically shrinking the human, as in *Atta*, by Bellamy (1953), or enlarging the insect, as in *Empire of the Ants*, by Wells (1905). As teachers, humanized insects were common in children's literature; often because they provided an amiable, impartial narrator or actor, with which the child can identify. For example, this was found in *James and the Giant Peach*, by Dahl (1961); and *Bugfolk*, by Terra (1979) referred to such hexapod characters as 'bugfolk.' An example of bugfolk was the caterpillar in *Alice in Wonderland*, by Carroll (1865). Some bugfolk became modern day folk heroes, like Spiderman, or villains like Mothra (as cited in Hogue, 2003).

Bee societies formed the basis for simile in a political satire against governmental hypocrisy in 18th century England, as in *The Fable of the Bees* or *Private Vices Made Public Benefits*, (Mandeville, 1714). Other examples of political and social satire employing insects were mentioned by Kevan (1788), as in *The Spider and the Fly,* a long English poem published in 1556 by Heywood, and *The Locust*, written by an anonymous author in 1704 (as cited in Dickie 2000).

Insect images appeared as frequently in poetry as in prose. The ancient Greeks often referred to insects symbolically and aesthetically, as did the Romans. Shakespeare played on many in his works, as did Dante (1320) in the *Divine Comedy*. Insects inspired many other poets, as well. Some, better known poems with insect titles were, *To a Louse*, by Burns (1786); *To-day, this Insect, and the World I Breath*, by Thomas (1914); *The Beetle*, by Riley (1916); and *To a Butterfly, the Redbreast and Butterfly*, by Wordsworth (1888) (as cited in Berenbaum (2000). Japanese poetry, particularly haiku, commonly incorporated insect allusions. One of the shortest poems ever written was about insects: *Ugh-Bugh!* (Kevan) (1788) (as cited in Launent, 2000).

Local names and folk taxonomies often reflected cultural beliefs in many cultures, such as Anglo-Saxon or Old English, Australian, German, Tibetan, Latin American, and Hellenistic. Hieroglyphs and pictograms depicted insect forms in ancient Egypt (scarab, bee, and grasshopper syllables in alphabet), Mayan, and Chinese writings (Tedlock, 1985).

In all languages, numerous insects or their names were enlisted as figures of speech (social butterfly), which were extended into often-used sayings and epigrams, like ‘Busy as a bee,’ ‘Don’t bug me,’ and ‘What is good for the bee is not good for the swarm.’ A number of manufactured and commercial objects bear insect names. Many cocktails (Grasshopper) or other drinks were so named, sometimes to suggest special potency (Stinger) or distinctive flavor (Bee’s kiss). Even English pubs and automobiles had insect epithets (Hogue, 2003).

Music and the Performing Arts

Insects invaded the world of music to a considerable degree, with composers seizing on various attributes to convey a mood or message. The rapid vibrato of *The Flight of the Bumblebee*, by Rimsky-Korsakov (1899-1900) imitated the buzz of the bee; the light of the firefly shone as a beacon to love in "Glow-Worm;" and butterflies imparted airiness, transience, and frivolity in "Poor Butterfly." The inspiration was less obvious in familiar songs such as *La Cucaracha*, *The Boll Weevil*, *The Blue-tailed Fly*, and unsung ditties like "Grasshopper Rock" and "Stompin' the Bug" (Hogue, 2003)

As direct emitters of pleasant sounds, stridulating types have long been esteemed by different cultures. Crickets and katydids kept in cages filled the house with cheerful chirps in several Asian countries and were once a passion of many Hamburgers (Laurent, 2000).

The insect was seen on stage for more than two millennia. Since Aristophanes produced "Spheces," or "The Wasps," in 422 BC, a number of dramas utilized metaphorical bugs, such as Sartre's (1943) "The Fly" and Karel and Capek's (1922) "Ze Zivota Hmyzu" (On the Life of Insects, or Insects Comedy) (as cited in Bodenheimer, 1928). Some insects reached more elegant heights in operas, such as *Madame Butterfly*, by Puccini (1903) and ballet, such as *Le Festin de L'Araignée*, by Rousel (1912). Ritual dances inspired by insects were discussed under Religion and Folklore, mentioned in this literature review. The cinema and television films were rife with insect villains, such as army ants in *Naked Jungle* (Paramount, 1954), and with a few comedic and heroic stars, as well (Hogue, 2003).

Graphic and Plastic Arts

Artists exploited the insect form in all media. Because of their pleasing colors and curious shapes, many types, especially butterflies and metallic beetles, were used directly for ornamentation (Akre, Hansen, & Zack, 1991). They also served as models for decorative jewelry, ceramics, textile designs, and a variety of other objects from prehistoric, historic, antique, and modern periods. Serving trays, ashtrays, and scenic montages made from the wings of butterflies (especially from the genus *Morpho* in South America) were familiar decorative objects, and insects were on the postage stamps of many countries (Bodenheimer, 1928).

Some particularly fine decorative pieces with insect designs were coveted art treasures; examples are the *Cretan Hornets* (Minoan gold pectoral with a pair of wasps) and solid gold fly pendants (*Order of the Golden Fly*) found in the funeral cache of Queen Ahotpe, an 18th-Dynasty ancestor of Tutankhamen (Akre et al.,1991).

Insects abounded in pictorial arts. They provided motifs for Neolithic artists', etching on bone and rendering on rock, representations of numerous insects existed in prehistoric petroglyphs and pictographs in Europe, South Africa, and North America (Hogue, 2003). One of the enormous figures laid out on the desert plains of southern Peru by the Nazca Culture (300BC-900AD) was a spider (Dickie, 2000).

Many portrayals of insects appeared in early European Christian religious art as universal symbols. Among these symbols were bees (mother: 'Mary' symbols), beehives (the church: *Madonna in the Garden* (Grünewald, 1517/1519), the stag beetle (evil: *The Virgin with a Multitude of Animals* (Dürer, 1503), flies (torment: *The Damnation of Lovers* (Grünewald), and scorpions (pain: many depictions of Saint Jerome in Penitence).

A special significance was attached to *lepidopterans* (symbolized by the goddess Psyche) as signatures of the soul (and hence life after death, change, rebirth) and love (Cloudsley-Thompson, 1976). For these reasons, they sometimes appeared in religious scenes (Dürer’s *The Virgin of the Irises*). Accordingly, butterfly or moth wings occasionally give powers of flight to some angelic forms (cupids) and often to fairies and nymphs (Clausen, 1954). The historic prototype for the biblical cherubs however, may have been dung beetles (Gagliardi, 1976).

Insect symbols were personal hallmarks of the works of a few famous contemporary artists, such as the surrealist Dali (grasshopper, groupings of ants, and formations of *muscoid* flies) and Hutter (butterflies) (Dickie, 2000). Because of their inherently provocative forms, odd species provided the principle themes in many paintings by other well-known western artists, such as Sutherland (aquatint series on *The Bees*), and in drawings and engravings of Escher (*Möbius Band*), Ensor (*Odd Insects*), Redon (*The Spider*), and many others of lesser fame. In illuminated medieval manuscript, border decorations and elaborate initials were often patterned after insects (Dickie, 2000).

Images of bug folk were common. Some of the earliest were fantastic insectoid demons in paintings by Bosch (*The Last Judgement*, details of fallen angel, 1504) and Brueghel (*Fall of the Angels*, 1562). These apparently spawned a style followed by a series of later illustrators, among them Disteli, Gerard, and Grandville (*Adventures d’un papillon* in *Scènes de la vie privée et publique des animaux*, 1842) and Aldridge (*Magician Moth* in the 1975 Grossman version of *The Butterfly Ball and the Grasshopper Feast*) (Gagliardi, 1976).

Some of the alien characteristics included antennae, bulbous and facetted eyes, articulated bodies, armored exterior, and biting mouthparts, and made insects favorite prototypes for the design of dream monsters, extraterrestrial creatures, and even spacecraft by fantasy artists. Numerous examples appeared on the cover of science fiction novels, on posters, and in cartoons (Turpin, 1992).

Sculpture also utilized insect motifs and symbolism. Best known from history was the frequent appearance of Psyche (represented by *lepidopteran* figures) on stone carvings of scarabs from classic Egypt and on Roman sarcophagi (Bodenheimer, 1928). Several contemporary artists working in metal, plastics, and other modern materials specialized in entomological themes (Dickie, 2000).

Insects and arachnid products have served as art media. Paintings were made on cobwebs (Cherry, 1993). Wax from both Apis and the tropical *meliponine* bees, were used to fashion lone figures and positive images for the 'lost wax' casting technique practiced by Old World and Incan metallurgists. Lacquer made from *lac* insects had a wide application in Oriental art (Laurent, 2000).

For their symbolic value, insects also appeared with regularity on seals, coins, and heraldic and other emblems. Napoleon I replaced the fleur-de-lis with the honeybee as the Bourbon family emblem, and its image was displayed on a number of surfaces in the royal palace and on the Napoleonic coat of arms (Akre, Hansen, & Zack, 1991). Twenty of the United States designated state insects, along with state flowers, trees, and birds: most chose the honeybee, a sign of industry and sovereignty (Hamel, 1991).

Advertising art frequently used insect images to convey overt or subliminal messages about products by capitalizing on widespread attitudes, either negative (cockroaches as bearers of filth) or favorable (beautiful, freshness, and airiness of butterflies). It is curious that insects depicted in art often bore only two pair of legs (Clausen 1954).

Interpretive History

Insects generally influenced human history, principally by forcing shifts in pivotal events (Kritzky & Cherry, 2000). Battles were lost, expeditions foiled, and populations decimated through the direct involvement of insects, usually as carriers of disease (Hogue, 2003). Insect products also helped to determine the direction of civilization's march. Some stated the Chinese Empire was founded on the silk trade (Hogue, 2003). Commerce in dyestuffs derived from the bodies of the *cochineal* insect reached global proportions by the 18th century, and proved so lucrative that the insect and its cactus host were introduced to various parts of the world from their native America (Akre et al., 1991). In the adopted countries, the plant spread and became a noxious weed that rendered vast tracts of land unusable. Trade in other insect products, such as honey and shellac, had similar economic significance. The Israelite band that founded the Jewish nation survived on 'manna' during its extended trek through the Sinai Desert. This nutritious substance was thought to have been extruded by scale insects on the tamarisk plant (Clausen, 1954).

There were anecdotes of a number of other ways in which insects crept into our affairs. A moth was supposed to have prevented an accident to a train on which Queen Victoria was riding. Several important personages were aided in difficult times, and inspired to lofty deeds, by insects and spiders. The Chinese inventor of paper, Ts'ai Lun (89-106 AD), according to legend, was shown the process by wasps making their nests by chewing tree bark and mixing it with their saliva (Berenbaum, 1995).

Philosophy

According to some, the insect was a low form of life that deserved only contempt, but it was justifiable to contemplate the rightful relationships between humans and insects. Most of what was written in this context dealt with the direct competition between insects and humans for food and fiber and the human suffering that resulted from insect-borne diseases (Kritzky & Cherry, 2000). Another favorite thesis was the comparison of insect and human societies.

Our comparatively shaky dominion of nature was also been a theme (e.g. in the motion picture *The Helstrom Chronicles,* (Wolper, 1971), and the insect was pointed to as the most likely form to inherit the earth after our own [human] presumed demise (as cited in Hogue, 2003). A few authors tried to look at the world through insect eyes (e.g. Franklin, "Soliloquy of a venerable Ephemera who had lived four hundred and twenty minutes") (as cited in Hogue, 2003, p. 95), and there was some appreciation of insects as friends and teachers. This was a generally neglected area, however (Hogue, 2003).

Religion and Folklore

Animalistic religious practices, based on insects, were an important part of the culture of many groups. From the ancient world, the best-known example was the scarab cult of the Egyptians (Clausen, 1954). Evidence in the form of scarab amulets dominated the archaeological records of those worshippers. Insect gods and goddesses assumed various roles in the religions of the Aztecs (Xochiquetzal, butterfly goddess), Greek (Artemis was Mylitta, the mother or bee goddess), Chinese (TschunWan, insect lord over crop pests), and Babylonians (scorpion men) (Hogue, 2003). The Hopi personified several insect spirits (Butterfly Man, Assassin Fly) in the form of Kachina dolls. In Bushman mythology, the mantis was an important god of creation, Kaggen. The insect deities were served with a variety of rites and rituals; for example, youthful initiates were scourged by stinging ants in puberty ceremonies among various Amazonian Indian tribes (*tucandeira*, Dynoponera spp., rituals) (Kritzky & Cherry, 2000).

Within the context of Judaism and Christianity, insects had no small role. Although most of the references to insects in the Bible were historical, some were allegorical or reflected deep theological meaning (stinging locusts in Revelation 9:3-11;113) (Clausen, 1954). Of the ten plagues visited upon Egypt preceding the Exodus, three were insects and two or three others may have had entomological connections (Hogue, 1987.). In the Talmudic literature, locusts were included among the disasters for which the sounding of the ram’s horn and a public feast were prescribed in the Ta’anit tractate (Section 3:5). Many religious artists favored the locust-plague theme.

Curious applications of entomology in the Christian religion were the exorcisms and animal trials performed by the Roman Catholic Church in medieval and even later times. Because animals, including insects, were supposed to possess human qualities, even a soul, they were held accountable for their misdeeds and were subject to divine control and excommunication (Clausen, 1954).

Involvements of insects in other major world religions (Islam, Hinduism, and Buddhism) were relatively unexplored by entomologists. The spider sitting in the center of the web was a spinner of illusion and reminded Hindus of Maya, the supernatural force behind the creation of the transient world. Hindu holy writings also taught that ants were divine; the first born of the world; ritually the anthill represented the earth (Hogue, 2003).

Entomological references in folklore (legends, beliefs, and fairy tales) abounded, but were generally ensconced in the anthropological literature and not easily located by the entomologist. There were no general reviews or collections of insect-based folktales, although a few limited treatises were available (Clausen, 1954). Insects were a part of many classical myths, legends, and beliefs. The Roman Goddess Psyche was portrayed with wings and represented rebirth and metamorphosis to a higher state. Butterflies and chrysalis were found in earlier Minoan iconography (*Ring of Nestor*), but the question of the age and origin of the symbolism was unsettled (Kritzky & Cherry, 2000).

Lilith, Adam's first wife and begetter of flies and demons, originated in Assyria-Babylon and made her way into Mohammedan and Jewish books. In a variant of the story of the aging of Tithonus, consort of Eos, he was turned into a cicada (Cloudsley-Thompson, 1976). Early natural historians told about the ant-lion (*myrmicoleon*), a giant ant that resembled a dog with lion's feet and dug for gold; it was portrayed in early bestiaries, sometimes in mongrel form with partial human anatomy. Other hybrids were the 'scorpion men' (human torso-legs/scorpion abdomen-tail) from second millennium Mesopotamia and neighboring times and places (Bodenheimer, 1928).

Other myths originated in European countries and were carried by emigrants to colonies in America and other continents as a variety of folktales. An exemplary and widespread folkloric theme was 'telling the bees' when a death occurred in a beekeeper's family. The insects were believed to respond sympathetically by attending the funeral or absconding (Kritzky & Cherry, 2000).

One arachnid, the scorpion, comprised the eighth of the normal 12 signs of the

Zodiac (Scorpio). A second, the spider, was considered by some astrologers to represent the 13th sign (Arachne) that became lost (Bodenheimer, 1928).

Folklore and superstitions involving insects were perhaps more prevalent in indigenous or traditional cultures than among industrialized societies. Every group had its repertoire, with common themes running across cultural lines (Tedlock, 1985). Many creation myths involved insects: The Hopis explained the origin of the world by the actions of the Spider Grandmother. According to the Yagua Indians of Peru, the Amazon River was created by the wood-eating insects and fire came from a mythical campfire ignited by fireflies, according to the Jicarilla Apaches of New Mexico (Hogue, 1985).

Involvement of insects in magic and witchcraft was infrequent considering the venomous and metamorphic powers of so many types. Many thought a few species were poisonous, such that even the slightest contact with them could cause instant or lingering, agonizing death (Fulgora in tropical America). A variety of interesting prophylaxes and remedies were employed against these imaginary assassins. A few species of insects had a supposed or real hallucinogenic or aphrodisiacal power, if ingested. This gave them a place in folk ritual (Hogue, 1985).

Folk healing used insects and their products, especially honey from the many species of wild and domestic bees. The word 'medicine' owed its origin to honey; the first syllable has the same root as *mead*, an alcoholic beverage made from honeycomb, often consumed as an elixir (Clausen, 1954). Cockroaches, lice, bedbugs (wall lice), beetles, and galls were used as medicines. As treatment for scorpion stings, village curanderos in the mountains of western Mexico tied a dead scorpion to the finger that was just stung (Cherry, 1993).

Recreation and Curiosities

Insects were the butt of many jokes or cartoons. Some people kept insects as unusual or educational pets, others for their pleasant sounds. Toys were modeled after insects, such as the familiar snapping 'cricket' noisemakers and a number of mechanical bugs. Other playthings may actually have incorporated living insects, including Mexican jumping beans or 'fly-powered' airplanes (Clausen, 1954).

Insects inspired diversionary pursuits, particularly in Asia, where kites, bull-roars, and other noisemakers of entomological engineering were common. In the martial arts, the stealth, strength, and speed of preying *mantids* formed the basis of one system of Kung Fu. Cricket and spider fighting were pastimes long practiced in Asian countries. In the West, 'flea circuses' were once widely attended; but by the 1950s were somewhat hard to find (Clausen, 1954).

Several apocryphal tales about insects, better called 'humbugs,' cropped up. There were fictitious species, such as winged spiders; Doyle's (1912) tick, '*Ixoedes maloni,*' which lived in the *Lost World*; iron-eating 'railroad or cannon worms;' and even alleged new species contrived from imagination, such as Stecker's (2007) *Gibbicellum sudeticum*. Some believed real bugs were behind some 'flying saucer' sightings. False fossil insects were common, especially in amber, but also from fabricated stone.

Ethnoentomology

Ethnoentomology was the applications of an insect's life in so-called primitive (traditional, aboriginal, or non-industrialized) societies and could be regarded as a special branch of cultural entomology. Its application took place alongside ethnobotany and was part of ethnozoology. It was discussed by Cherry (1993) as a curiosity.

A number of Native American groups adopted insects as totem figures and as a source of animistic explanations in their religions and cosmologies. This was especially true of groups inhabiting tropical areas, probably because of the richness of insects in their surroundings. Scientists investigated the ethnoentomologies of the Warao of the Orinoco Delta and the Gorotire Kayapó of Amazonia. Other studies outside of South America included those with indigenous tribes in Zambia and Maoris in New Zealand, and with the Kalahari Bushmen (Hogue, 1985).

The best-documented studies among the North American Indians were the ethnoentomologies of the Navajo and the Hopi, although other groups also received some attention. Insects were a part of the iconography of the Aztecs of Mexico. Insect artifacts and remains were used as topographic and chronologic indicators in other ethnological works, as well (Hogue, 1985).

Species of Special Cultural Significance

Several types of insects acquired special cultural importance, often for multiple reasons. Orthopteroids (*grigs*), including *mantids*, had a wider variety of meanings than any other insects. Locusts commanded special recognition, because of the destructive force of their plagues. Butterflies and moths had at least 74 symbolic meanings in Western art, according to Gagliardi (as cited in Clausen, 1954). They were also important to ancient cultures in Mexico. Bees were nearly culturally ubiquitous, having evoked a considerable number of superstitions and symbolic applications. Others with a particular place in the humanities were dung scarabs (also mentioned in the Religion and Folklore section) and cicada. Amulets in the form of cicadas were placed on the tongues of the dead in China, to induce resurrection by sympathetic magic. Fleas, fireflies, and flies (generally *myiasis*-producing flies), ectoparasites, dragonflies, spiders, and scorpions, all carried exceptional meanings in human culture (Kritzky & Cherry, 2000).

Several erroneous beliefs, superstitions, and myths evolved from the mimicry existing between the drone fly (*Eristalis tenax*) and the honeybee. Most curious was the 'bugonia' myth, which was an ancient belief that honeybees may arise from animal carcasses, especially dead oxen or cattle. The development of these bee-resembling flies on putrefying flesh must be the basis of the story (Clausen, 1954).

As one conspicuous part of the environment, insects, along with plants, other animals, and geological features, captured human imagination and became incorporated into human thinking from the earliest of times. Almost no aspect of human culture was untouched by these creatures. Their cultural importance relative to that of other life forms was, at one time, not known, because comparative study had not yet been conducted. It was clear that culture was another sphere in which their adaptability compensated for the alien arthropod form and comportment. In spite of a hard external skeleton, extra appendages, and robot-like instincts, arthropods still sufficiently paralleled humans in structure and behavior to serve as models of friends, enemies, and teachers (Hogue, 2003).

There were various explanations for the significance of insects in human culture. Their meaning most often rested on symbolic value. Because of some outstanding part of their appearance or behavior, many species were well-established symbols, some with multifarious meanings. These meanings were sometimes contradictory depending on the society in which they appeared (e.g., a cricket in the house may signify either good luck or impending doom). The insect itself or its products may also provide a model (decorative art), a device (toy), or a tool (murder weapon in a detective story) (Berenbaum, 1995).

Entomological Research

Research on entomological problems could focus on the effects of insects on people, food shortages, and disease throughout the world (Esser, Crowder, & Milosavljevic, 2015). The value of such research was to create a context for learning the fundamental principles of taxonomic studies. Entomological research used a collection-based study, collecting genomic data, morphology, or evolution history to understand how global insect diversity related to the broader field of biology.

Research was a process to discover new knowledge. "A systematic investigation (i.e., the gathering and analysis of information) is designed to develop or contribute to generalizable knowledge" (Garcia, 2013 p.1017). The National Academy of Sciences stated that the object of research was to "extend human knowledge of the physical, biological, or social world beyond what is already known" (National Research Council, 2012 p. 103). Research was different from other forms of discovering knowledge (like reading a book), because it used a systematic process called the Scientific Method (Bell, 1993).

The Scientific Method consisted of observing the world around the investigator and creating a hypothesis about relationships in the world. A hypothesis was an informed and educated prediction or explanation about something (Bell, 1993). Part of the research process involved testing the hypothesis and then examining the results of the tests as they related to both the hypothesis and the world around the investigator. When a researcher formed hypotheses, these acted like a map through the research study. They told the researcher which factors were important to study and how they might be related to each other or were possibly caused by a manipulation that the researcher introduced (e.g. a program, treatment, or change in the environment). With this map, the researcher could interpret the information he/she collected and could make sound conclusions about the results (Cartier, Rudolph, & Stewart, 2001).

Research was possible with human beings, animals, plants, other organisms, and inorganic matter. In research with human beings and animals, specific rules about the treatment of humans and animals created by the U.S. Federal Government must be followed. This ensured that humans and animals were treated with dignity and respect, and that the research caused minimal harm.

No matter the topic studied, the value of the research depended on how well it was designed and completed. Therefore, one of the most important considerations in solid research was to follow the design or plan developed by an experienced researcher (PI). The PI was in charge of all aspects of the research and created the protocol (the research plan) that all people doing the research must follow. By doing so, the PI and the public could be sure that the results of the research were real and useful to other scientists (Gall, Gall, & Borg, 2007).

Entomologist

An individual who studied insects or entomology was an entomologist. Most individuals who practiced entomology considered it a hobby or interest, due to the beauty and diversity of these creatures. Colleges or universities, governments, or companies dealing with pest control typically employed professional entomologists, or persons who made a living working with insects (Turpin, 1992).

Entomologists study insects' habitats and how insects evolved. They also develop ways to control harmful insects. They research and control insect-borne diseases, and discover and study new species of insects. They also taught students about insects and created public awareness about insects in general. At the time of this writing, there were nearly a million known species of insects, and thousands of new species were discovered every year. Insects made up over three-quarters of all the species of animals. All insects played roles in ecosystems. Some roles were beneficial and some harmful to humans. Bees, for example, pollinated plants and produced honey. Many other insects helped bacteria and fungi break down organic matter and form soil. Some insects damaged growing crops and spoiled harvests in storage (Gillott, 1985).

Entomologists had the option of working in several different fields. Although all of them dealt with bugs, some entomologists chose to work in an agriculture or forestry environment. Others might decide to work with bees (apiculture), or in veterinary entomology, insect ecology, or medical entomology. Entomologists often worked with other scientists to try to solve a particular bug problem, such as the spreading of an insect-borne disease (Lincoln & Guba, 1985). All levels of government employed many entomologists. Universities, pest control companies, and even chemical producers may also employ entomologists. Entomologists spent time in both the field and the lab.

Hands-On Learning

Science first came into the mainstream of education as selections of didactic literature in the 18th and 19th centuries (Craig, 1957; Underhill, 1941). By the mid-1800s, reading material in science comprised about 20% of what a student would learn (Rillero & Rudolph, 1992). For some students at the time, this remained their only educational exposure to science.

> American pedagogy in the 19th century was disheartening. Teaching was by memorization and conditioning exclusively during this period. Encouragement to learn was by the rod. Reverence and duty (to God, folks, and schoolteacher) made the establishment for the dwelling of schooling as a whole. (Withers, 1963, p. vii)

Pestalozzi was among the first to encourage independent investigation by students, as contrasted with rote learning from a textbook (Elkind, 1987; Rillero, 1993). During this rebirth of education, many assumed it was perilous to believe something was true without first testing and examining it in nature. Powerful figures in society, who were also experts in many different fields, began to change the nature of public education (Thorndike, 1920).

The ideas of Pestalozzi spread across America in the 1860s, including the idea of using objects for teaching. The Teaching Revolution movement challenged the domination of textbooks in schools and encouraged progressive knowledge-building by students. Effective teaching methodologies became common in science education and included laboratory experiments and excursions beyond the classroom (Rillero, 1993).

In subsequent decades, the Committee of Ten was influential in securing the inclusion of science as a permanent part of the educational curriculum. For example, the Astronomy, Chemistry, and Physics Committee of the NEA in 1893 recommended that students, beginning as early as elementary school, should do hands on science with the everyday things around them. The same committee also declared, “The use of textbooks is suitable and unquestionably crucial to learning, but the exercise of examining items and natural phenomena by using the senses must not be lost" (National Education Association, 1893, p. 119). The Natural History Committee agreed with the recommendation. They stated that a ‘no textbook policy’ was appropriate at the elementary level. As the students aged, they should continue to use common items as part of their science classes. The project method of hands-on learning thus came into being. McMurray (1921) said these projects were important for the students to both start and finish and would provide a foundation for later learning. McMurray (1921) created a list of 37 projects to be completed by students, in sequence, with school and home activities focused on gardening. He designed alternative science tasks that included:

> Building tree houses, constructing and hanging a gate, concreting a basement floor, creating a corncrib, making a tool chest, wallpapering and dressing up a living area, planning and laying slabs of tile for drainage, and supplying the kitchen with running water. (p. 20)

Such projects allowed children to discover the practical benefit of science in its real-world applications. Students in schools did not need abstract scientific principles of thought or explanation. Instead, they needed an actual demonstration of scientific ideas, as related to their homes and neighborhoods. Observed prominent philosopher and educational reformer Dewey (1921) stated, “These are pre-eminently necessary and useful science topics, that must be given the ability to grow in the curriculum at large” (p. 8). One scholar described Dewey’s (1921) “ideology of students’ education” as “an advocacy of the project-based method of learning” (as cited in Smith, 1999, p. 187).

By the mid-20th century in the U.S., school curricula embraced the idea of hands-on learning in science (Hodson, 1990; Tobin, 1990). In the 1970s Helgeson, Blosser, and Howe (1977) called for "more 'hands-on' science rather than reading about science, and use of a greater variety of media and materials for teaching science" (p. 17). A variety of labels was used for a modern-science curriculum, including 'inquiry,' 'problem-solving,' and 'scientific process.' Respectively, various areas of study joined this idea of 'hands-on' experiments and experiences to acquire greater depths of understanding of the fundamental idea of science (Welch, 1979).

McAnarney (1978) stated, "over the span of 10-15 years, bottomless focus has been on the improvement of elementary school programs [. . . in] science that uses hands-on experiences to understand the phenomena of science" (p. 36). This was the beginning of so-called 'second-generation' curricula by way of differentiating them from their 'first-generation' antecedents in the 1960s.

Hands-on learning was the paramount viewpoint of the modern constructivist view of what the public should know and be able to do (Loucks-Horsley et al., 1990). Flick (1993) offered this comprehensive overview:

> After a quarter of a century, the familiar phrase hands-on science is now a part of the informal discussion of elementary science. Teachers, administrators, publishers, and trade books all refer to the importance of hands-on activities in science instruction. They are nothing short of a revolution. Descriptions of science education at all pre-college levels have shifted from vocabulary and text material to activities, inventions, and even project-based Olympics. (p. 1)

High-Poverty Schools

A high-poverty school was one with more than 50% of its pupils eligible for free or reduced-cost lunch (Tilley, 2011). A significant amount of research was concerned socioeconomic status and family environment was predictors of a student's ability to achieve (Coleman et al., 1966; Jencks et al., 1972). Kozol (1991) formulated the best analysis of how poverty and education were connected. Kozol (1991) established that schools in lower socioeconomic districts were grossly understaffed and underfinanced. Moreover, he found the focus of education interwoven with poverty (Tilley, 2011; Atweigh, Bleicher, & Cooper, 1998; Oakes, 1990; Tate, 1997). Schools in low socioeconomic districts, rather than focusing on developing skills in critical thinking, emphasized rote learning, and minimal levels of proficiency (Haberman, 1991; Knapp & Woolverton, 1995). Impoverished districts also tended to have inadequate school facilities and unqualified or inexperienced teachers (Ingersoll, 1999).

Socioeconomic conditions persisted as the main factor in students' academic outcomes (Tilley, 2011). This was true in many of the large industrial countries, such as the U.S., Canada, and various European countries (Levin, 2007). In addition, a student's household income continued to be a reliable predictor of student accomplishment (Coleman et al., 1966). Learners in a low-income and high-poverty setting had a greater chance of underachieving than their peers elsewhere and were more prone to dropping out of school (Florida Department of Education, 2008). These students also had a higher probability of being either placed on school suspension or held back in their current grade level (Wood, 2003). Sirin (2005) completed a meta-analysis of research studies showing the correlation between socioeconomic status and learner performance from 1990 to 2000. It established a substantial relationship between socioeconomic status and student accomplishment over time. More recent studies than the one completed by Sirin (2005) provided further evidence of this association.

The 2005 National Assessment of Educational Progress (NAEP) indicated that only 13% of students attending schools in impoverished areas received a score of proficient, versus 40% of students in other settings. Forty-nine percent of the student population in impoverished areas scored below the cutoff for basic understanding, versus only 21% of students elsewhere (Murnane, 2007, p. 167). The NAEP exams in reading, math, writing, and science showed a majority of learners who qualified for free and reduced-cost lunch were scoring at the bottom tier of achievement (Guilfoyle 2006). This pattern held true for underprivileged students in the fourth, eighth, and 12th grades throughout the U.S. Similarly, student scores on the Scholastic Aptitude Test correlated positively to family income (Taylor, 2005). High-poverty schools also had fewer qualified staff members, a greater rate of personnel turnover, and far lower resources per student, than schools in other settings (Machtinger, 2007).

Educational facilities in disrepair were a common outcome of inadequate funding (Gunzenhauser & Hyde, 2007). The power of poverty was so strong that some researchers developed different ways of viewing multiculturalism and the effects of poverty on communities (Hanushek & Raymond, 2005; Hargreaves, 1995). Writers frequently attributed low student achievement in poverty-stricken environments to lack of effort and ability, with little or no consideration given to the root causes and significant effects of poverty (Taylor, 2005). Consequently, from different studies, a viewpoint started to arise in the U.S. that school districts with a large number of low Social Economic Students (SES) learners hampered students' chances of achievement in all areas of education (Hoy & Hoy, 2003; Illinois State Board of Education, 2001).

However, other researchers found exceptions to the SES rule (Jennings & Retner, 2006; Edmonds, 1979; Jencks et al., 1972). Their studies found some high-achieving, low-SES schools, as well as some common components of effective leadership in those schools (Dyrli, 2008). The differences that existed in such schools were in the areas of instructional leadership, academic focus, high expectations, and school climate. One researcher suggested that answerability was a means for improving student achievement levels in impoverished urban schools (Glickman, 1992). Some believed that accountability and incentives could advance low-SES students' academic success (Murnane, 2007).

The recommendations by Murnane (2007) for expanding accountability standards incorporated state testing that would allow low-income students to meet these standards. Further suggestion involved changing graduation requirements to match the competencies required to succeed after high school. Additional sections, such as designing the "instructional capacity of the school so that it can educate low-income children" (Murnane, 2007, p. 163) got to the point of student accomplishment in urban schools. Another compelling step was reconsideration of how to teach students from low socioeconomic backgrounds, a neglected issue in the past, by the standards-based reform movement (Murnane, 2007). Recognizing that urban schools needed specially trained teachers, Tilley (2011) made the suggestion to establish competitive matching funds, such as grants or scholarships to attract and retain outstanding educators in the high-poverty school setting.

As reported by Murnane (2007), one respondent asked, 'What can be done to develop high-quality teachers?' Other researchers asserted that students in urban schools needed a "rigorous curriculum with meaningful homework and assessment" (Machtinger, 2007, p. 4). However, the learning opportunities that students with low SES often received was the polar opposite of those benefiting higher SES learners. A dearth of well-qualified teachers lowered the caliber of education in urban schools (Resnick, 1995). Many researchers proposed that hard work and more learning experiences would be a remedy. Others claimed that schools could not overcome the impact of socioeconomics (Levin, 2007). Such research understandably could be discouraging to educators, who wanted to believe that schools with high percentages of students living in poverty could fulfill their mission as responsibly as schools that are more affluent.

Teacher Education

The nature and acquisition of teacher-preparation knowledge was studied for over half a century (Abell, 2007; Calderhead, 1996). Early research in the 1960s sought to describe teacher knowledge with the intention of determining how it influenced instruction and consequently student achievement (Calderhead, 1996). In the 1980s, a dramatic shift took place in the research-base of teacher knowledge. Instead of continuing to examine the 'known,' attention was directed toward the 'knowers' — the teachers. Shulman (1986, 1987) led a research program that attempted to uncover what knowledge was essential for teachers to know. His model of teacher education would eventually become the foundation for the preparation of future science teachers (Abell, 2007).

Shulman (1986) asked, "How might the expertise that spawns in the genius of educators expand into a focus on the idea of content-driven education?" (p. 9). He suggested that educators differentiate between the three pathways of content knowledge:

curricular knowledge, pedagogical content knowledge, and subject-matter content knowledge. The idea of subject-matter understanding referred to an educator's mastery of the facts of an individual discipline, and how those were organized, tested, and validated (Calderhead, 1996). Curricular knowledge referred to a teacher's understanding of the materials relevant to his or her discipline, including "the ideas and issues they contain, and the concepts of organization, coherence, and progression that underlie them" (Calderhead, 1996, p. 716). Beyond these two types of knowledge, Shulman (1986, 1987) asserted that classroom teachers had a third kind of expertise enhanced through instructional experience in a particular subject area. Abell (2007) called this pedagogical content knowledge (PCK). Shulman (1986, 1987) regarded curricular knowledge as distinctly separate from PCK. For the purpose of this literature review, the researcher will adhere to Magnusson, Krajcik, and Borko's (1999) characterization of curricular knowledge as a component of PCK.

PCK represented the mixing of content and pedagogy into an apprehension of how particular topics, problems, or issues can be organized, and made suitable to the diverse interests and capacity of learners, and given for instruction" (Shulman, 1987, p. 8). Shulman (1986) believed that PCK must include a teacher's ability to elucidate ideas through analogies, examples, explanations, illustrations, and demonstrations (as cited in Smith, 1999). Over time, Shulman's (1986, 1987) model was debated and reinterpreted. Van Driel, Verloop, and de Vos (1998) reported that no universally accepted definition of PCK was accepted in the research community. For example, Grossman (1990) divided PCK into four categories: conceptions of purposes for teaching subject matter, knowledge of students' understanding (including misconceptions and difficulties), curricular knowledge, and knowledge of instructional strategies. Informed by the work of Grossman (1990), Magnusson et al. (1999) asserted, “The pinpoint feature of pedagogical content understanding is its conceptualization as the result of a transformation of knowledge from other domains” (p. 104).

Magnusson et al. (1999) stated there were five components of science teachers’ PCK: orientation toward science teaching; working knowledge of and beliefs about a science curriculum; a working understanding and acceptance of students’ perceptions of specific science topics; working knowledge of and beliefs about assessment in science (p. 110); and knowledge of and beliefs about instructional strategies for teaching science. Abell (2007) suggested that PCK included, “orientations, knowledge of learners, curriculum, instructional strategies, and assessment” (p. 1121).

Regardless of the definition of PCK, most researchers supported two elements of Shulman's (1986, 1987) original model. The first was knowledge of a subject, and the second was an understanding of students’ learning difficulties (Van Driel, Verloop, & De Vos, 1998). Teachers who possessed well-developed PCK understood the various ways subject matter could be presented to address the different needs of students in their classrooms. Such teachers were flexible in their instructional strategies. Through familiarity with the preconceptions and misconceptions students brought to the classroom, teachers adjusted their practices to anticipate possible learning roadblocks.

Developing PCK

Hanuscin, Lee, and Akerson (2011) maintained that PCK was developed during the repeated experience of teaching a particular topic in the classroom. Similarly, Van Driel et al. (1998) argued that PCK, or as they termed it ‘craft knowledge,’ involved the transformation of subject-matter knowledge through experience. Craft knowledge referred to the professional knowledge that teachers used in their everyday teaching, including strategies, tactics, and routines (Brown & McIntyre, 1993; Calderhead, 1996). Gage and Berliner (1998) suggested that there were five stages in the acquisition of craft knowledge.

First, novice teachers sought out “rules and recipes to guide their actions and improve their understanding” (Calderhead, 1996, p. 717). Second, teachers transitioned to an advanced beginner stage in which they came to understand that it was sometimes appropriate to break the rules. In this stage, they also became strategic in their instructional choices. Third, teachers attained a level of competence such that they made conscious decisions and adaptations regarding their instruction. Fourth, teachers became proficient to the point where knowledge became intuitive and their actions more holistic. In the final stage, teachers’ practice was “characterized by fluency and automaticity in which the teacher is rarely surprised and is fully adapted to an end role in the situation” (Calderhead, 1996, p. 717). Although pre-service teachers may possess an adequate understanding of a subject, their lack of experience in the classroom explained their lack of PCK. Beginning teachers spent their first years of full-time teaching on determining the relationships among concepts (Calderhead, 1996). This knowledge-building process was critical to a teacher's ability to communicate these relationships to students.

Elementary teachers often lacked confidence in teaching science (Appleton, 2003; Smith, 1999; Tilgner, 1990). Elementary teachers “often think that they need to know the actual science content so that they can tell or show children the ‘right’ answers” (Smith, 1999, p. 173). In addition, they may have naïve conceptions of scientific topics. When such teachers were unable to recognize student misconceptions, their PCK cannot develop adequately (Smith, 1999).

They did not probe students' thinking with appropriate questions that revealed or refuted prior conceptions. Instead, these teachers tended to design lessons that focused on student engagement, discovery, or the scientific method (Appleton, 2003; Smith, 1999). Elementary teachers could develop greater PCK by listening to their students' ideas about science content. Engaging in activities where students can openly express their questions and thoughts was a comfortable activity for these teachers (Smith, 1999). During this time, teachers began to examine their own ideas, knowledge, and practice. In fact, some experienced elementary teachers have reported that this process of exploring children's ideas facilitated the greatest change in their classroom practices (Smith, 1999).

Alternatively, Grossman (1990) claimed that teachers acquired some PCK through traditional curriculum and instruction courses in teacher-education programs. Such programs attempted to teach pedagogy to pre-service teachers through theory courses, method courses, and practical experiences (Tamir, 1988). However, knowledge of pedagogy may suffer when a lack of coordination existed between course instructors and hands-on supervisors. This was especially true when the pedagogical beliefs of mentors in the field conflict with those of academic instructors responsible for theory and methods.

It was debated whether pre-service teachers retained pedagogical knowledge after completing their coursework. Baxter and Lederman (1999) claimed that PCK was different from content knowledge and general pedagogical knowledge. They posited that PCK was an internal construct in which teachers combined content knowledge and pedagogy to help address students' difficulties with particular topics. The research conducted on PCK in science education lacked coherence, but this may be in part because of the complex nature of PCK and the problems researchers faced when assessing an internal construct (Abell, 2007).

Abell (2007) stated that observations provided only a limited view of PCK because researchers cannot see into the teachers' heads to understand the decision-making process by which they choose certain methods and examples to address content. PCK was often subconscious. Sometimes teachers were unable to express their thoughts and beliefs about their practice, and sometimes they refrained purposefully from so doing.

Previous attempts to assess teachers' PCK included the use of instruments with Likert-type, multiple-choice, and short-answer formats (Kromrey & Renfrow, 1991). However, these forms assumed that there were 'right' answers to pedagogical questions (Baxter & Lederman, 1999). Another way in which researchers attempted to assess PCK involved concept maps and card sorts. Concept maps asked teachers to draw relationships between key terms of a particular topic or idea. The teachers might group words, draw pictures, or explain their thinking about a concept. Card sorts required teachers to place cards in an arrangement that illustrated the relationship between pre-identified concepts or items. Both methods required teachers to indicate relationships between ideas. However, both methods also restricted responses (Baxter & Lederman, 1999).

Other researchers have attempted to address these limitations by using open-ended questions. By sorting participants' responses, they were able to categorize them.

Kagan (1990) suggested that the resulting concept maps measured only short-term changes in thinking, meaning that this approach had little long-term value concerning PCK. Baxter and Lederman (1999) stated that in order to assess PCK most studies relied on multiple methods, triangulating data collected from interviews, concept maps, and video-prompted recall. However, studies that used multiple methods to assess PCK might be difficult to replicate and were challenging to complete because of their comprehensive nature.

Insects

The Greek word *entomon* referred to the creatures known as insects. Insects' physiology was entirely different from that of a human. Their anatomical structures provided clues to understanding how life could survive in various conditions. Many insects were also valuable ecologically, because they controlled undesirable pests and pollinated fruits and vegetables. Entomology, or the study of insects, thus allowed educators to gain a better understanding of nature's dynamics (Turpin, 1992).

Insects developed over time several biological advantages that allowed them to survive in different habitats successfully. The first advantage was its exoskeleton, which provided protection and helped to control moisture loss. This exoskeleton allowed insects to move from sea to land before other creatures. The second advantage was size. Because insects were small, they were able to occupy different areas of the world and exploit them to survive (Turpin, 1992). Next was the ability of many insects to fly. Flight was an adaptive response used to escape enemies and travel into new areas. Another advantage was the developmental process known as metamorphosis (Turpin, 1992). As metamorphosis happened, insects changed into an adult stage that looked vastly different from its immature life form. This change allowed insects to have access to different resources used to promote the species' continuation (Turpin, 1992). Still another advantage was that insects could stay in the larval stage for extended periods until conditions were favorable for their survival. The final advantage was their ability to reproduce rapidly and in great numbers (Turpin, 1992).

Next Generation Science Standards

The advent of NGSS transformed science education in K-12 school settings. Before this innovation, teachers taught various domains of science separately by content, apart from actual practice. NGSS, on the other hand, assumed that learners of all ages used different science studies as a framework for acquiring new knowledge (National Research Council, 2013c). NGSS thus called on educators to administer the crosscutting concepts that connected the fields of science and engineering. This included ideas, such as cause and effect, as well as structure and function, to expand students' understanding of foundational scientific ideas (National Research Council, 2013c). The designers expected that the performance intention for learners using the NGSS model followed the combined, three-dimensional outline as a possible route of learning science for all pupils. The NGSS principles were noteworthy for many reasons (National Research Council, 2013c).

Many state departments of education and science partners created the new standards based on a National Research Council (2012) report. This report was titled, "A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas" (Framework for K-12 Science Education). A committee of scientists, educators, researchers, and leaders from various states wrote the document. Its intent was to create, simultaneously, the foundation of science standards while developing a foundation of core scientific goals (National Research Council, 2012). The project allowed students to access different levels of understanding scientific phenomena as they progressed through school. Framework for K-12 Science Education also called for a more defined focus on scientific inquiry in education (National Research Council, 2013a). K-12 students, it maintained, must have equal opportunities to practice the scientific process in school settings. Teachers urged to complete in their classrooms to identify scientific interests and cultural practices consistent with students' everyday lives (National Research Council, 2013b).

The formulation of Framework for K-12 Science Education involved 26 states, 41 writers from across the country, and hundreds of educators, scientists, researchers, and engineers (National Research Council, 2013c). Each participant provided observations on the preliminary draft of the document. As of mid-October 2015, 11 states and the District of Columbia had adopted NGSS as their focus in revamping science curricula and using grade-level expectations as a guide. The NGSS were vastly different from the Common Core State Standards created for English, Language Arts, and Mathematics. NGSS focused on distinct pathways to the Common Core State Standards for each scientific field (National Research Council 2013c).

Over 10 years of research on science standards in education paved the way for adopting NGSS. Curricular materials became the blueprint for how any student would encounter the standards for science education. They also provided a means to help educators advance their own methods (Davis & Krajcik, 2005). Exercises created to improve instruction included the means for pupils to complete science assignments. One example was lab equipment. According to NGSS, these tools must be accessible to all students in a school. Davis and Krajcik (2005) evaluated research-backed curricular materials designed to improve education in science. As of this writing, no single array of materials had been completely coordinated with the NGSS. School districts intertwined their science and engineering curricula to get a more robust program under the new standards. This combined system focused on explaining difficult concepts and developing models in the classroom itself.

Development of the science educator was a stepping-stone for carrying out the first generation of standards. This professional development focused on teaching general content in science. It presented different avenues for promoting student-centered education (Garet, Porter, Desimone, Birman, & Yoon, 2001; Supovitz & Turner, 2000). Exceptionally useful approaches included supporting teachers in determining classroom practices (Heller, Daehler, Wong, Shinohara, & Miratrix, 2012; Roth et al., 2011) and preparing them to utilize high-quality instructional materials (Penuel, Gallagher, & Moorthy, 2011).

When the new standards based on Framework for K-12 Science Education were introduced to districts across the country, teachers and school administrators needed to adapt to them, as reforms started to modify day-to-day events (Weinbaum & Supovitz, 2010). Administrators needed hard data about the implementation of NGSS to monitor whether or not reforms were working. This data mining allowed administrators to design better support for implementation (Penuel, Harris, & DeBarger, 2015).

Reports recent to this writing concluded that assessing student' opportunities to learn science was critical, primarily in order to promote equal opportunity to learn

(National Research Council, 2013a, 2013b). Monitoring opportunities to learn focused on whether there was adequate time allotted to science instruction, access to high-quality curricular materials, necessary equipment for investigations, and access for all teachers to professional development.

Few assessments were made of how students applied crosscutting concepts and core ideas in science within the classroom (Penuel et al., 2015). Educators needed to develop tasks that strategically monitored not only a student's progress toward NGSS proficiency, but also how that student was able to connect ideas later on from earlier studies. This expectation involved coordinating instruction and lesson designs across different grades. School districts across America created a new arrangement of formative and summative assessments. No single test calibrated all the learning outcomes for any grade level in the U.S. (National Research Council, 2013a). The work became vital when different departments of education began to use assessments of student progress per the new standards.

Putting NGSS into action required students, teachers, and administrators to chart a pathway for success. Some forgot that putting into practice new standards required laying out a blueprint of learning opportunities for everyone. Teachers needed to learn on the fly how to address challenges that arose with the rolling out of this process. The success of NGSS depended on teachers' thinking of themselves as co-learners during the process of implementation (Hassard, 2011).

Numerous groups, such as the National Science Teaching Association and the Science Teachers of Missouri worked to strengthen the adoption of the Framework for K-12 Science Education. These organizations met the aggressive goals for achievement associated with implementation of the NGSS. Those organizations included professional organizations of science teachers as well as business entities. NGSS were a planning structure for the long haul (National Research Council, 2013a).

Schools leaders created an infrastructure for improving learning opportunities in science education. These educational leaders could promote continuous development in science content at all levels, provide materials to establish and sustain teams of teachers, and design curricular options that responded to NGSS (National Research Council, 2013a). Educational leaders at all levels were essential in implementing and showing the scope of science learning for students by allowing strategies that worked with learners' different styles and showed resources for fair access to meaningful science learning chances and equal participation in science classrooms (National Research Council, 2013c). The new standards ensured a more objective system of education in science that prepared students to achieve in the classroom and transfer those skills to the outside world (National Research Council, 2013c).

Project-Based Inquiry Science

A group of top scientists, who were specialists in learning scientific concepts, created Project-Based Inquiry Science (PBIS) educational units with help from the National Science Foundation (Penuel et al., 2011). PBIS emphasized how students learned science in the classroom. The program demonstrated positive, long-lasting effects in the education of all groups of students from any background. The first study took place in a large urban district with high percentages of low-income students.

Penuel, Harris, and DeBarger (2015) studied PBIS professional development organized over many sessions during the two years of the research project. The study provided background on what three-dimensional learning looked like in science. For example, in one lesson teachers had to collaboratively make a model of what happens when air molecules compress and expand in an apparatus, such as a syringe. The participants tried to explain this phenomenon with sketches of what happens when a plunger moves inside a plastic syringe. This lesson helped the teachers to acquire valuable pedagogical experience with the phenomenon of air density. The participants also studied the fundamental nature of models for science and the use of them within a system. This was a step that led to the three-dimensional NGSS crosscutting concept (Penuel et al., 2015).

In the PBIS study, the participants also completed reflective teaching journals, which explained to the researchers and stakeholders how far into a unit they were at any given moment. The study by Penuel et al. (2015) then obtained video recordings of some participants at work, as well as samples of assignments and student work related to the assignments.

The group next had to devise tests that aligned with the NGSS learning goals. This alignment pursued through a process called evidence-centered design (Penuel et al., 2015). The educators then piloted their work and revised their processes based on evidence of student achievement in the classroom. The assignment involved two science practices at the center of learning: constructing explanations and developing models.

All undetermined tasks in the PBIS study for assessment required that students demonstrate a broad sense of a core process by engaging in practices that showed such understanding. The rules for each of these different tasks unified a scientific core idea, practice, and a crosscutting concept established by NGSS (National Research Council, 2012).

Student Learning Outcomes

Learning outcomes related to how a student matures cognitively were a central focus that established the quality and standards of education (Ogundokun, 2011). Researchers investigated how students engaged with and experienced learning in educational settings for a long time (Ginns, Martin, Liem, & Papworth, 2014). Student learning outcomes could include traditional measures of learning such as school-based assessments or external evaluations.

Student Self-Assessment

The essence of education was to develop students' capacity to make judgments about their performance (Boud & Falchikov, 2007). Self-evaluation in any course of study enabled students to focus on the most important aspects of their work for improvement. If students were not able to assess the quality of their work, they would be ill equipped for most professional or even non-professional jobs. Thus, developing the capacity to make self-judgments of performance should be an assumed outcome in any educational setting (O'Donovan, Price, & Rust, 2008).

Research on student self-assessment suggested that certain things needed combination with the art of self-assessing (Boud, 1995). Building the thought process to make intelligent choices was important in any educational program (Boud & Falchikov 2007). How might such capacity for judgment be encouraged? Many believed that under the right conditions K-12 students could review their execution by means of common formative and summative assessment (Boud & Falchikov 1989; Dochy, Segers, & Sluijsmans, 1999). Less apparent was students' performance in criteria-based assessment contexts and the circumstances in which their judgment could improve (Ward, Gruppen, & Regehr, 2002; Galbraith, Hawkins, & Holmboe, 2008).

Many assessment systems did not include the capacity to make judgments. Rote knowledge was often the basis for formative and summative assessment items, with academic criteria set by teachers in a local school district. This orientation cultivated a dependency on teachers' authority rather than developing students' independent judgment of their learning, and it not necessarily promoted by the addition of simple self-assessment interventions (Boud, 1995). Rigorous assessments involved more than the self-testing of students. Sadler (1989) posited that skills in self-evaluation needed development "by providing direct, authentic evaluative experience for students" (p. 119). Such skills needed building systematically throughout individual courses of study (Dreyfus & Dreyfus, 2004).

The key feature in the development of judgment, like any other kind of competence, was that it required consistent commitment (Ericsson, Krampe, & Tesch-Romer, 1993). Norms for the character of work needed to gauged and explained. Then these norms needed to apply in the work of the student. Different standards for various types of work were required, and students needed extensive practice in evaluating their work. Students had to learn how to see their work with sufficient distance in order to be able to apply realistic standards.

Sadler (1989) indicated that students developed skills in evaluating the quality of their work through gradually moving away from "teacher-supplied feedback to learner self-monitoring" (p. 143). Students learned by consistently making their own evaluations and relating them to the assessments of others. Such endeavors required input from practitioners or peers who could verify correct judgments. As Sadler (1989) described it, "Providing regulated but direct and convincing evaluative involvement for students empowers them to advance their evaluative understanding, thereby bringing them within the guild of people who can determine quality using various norms" (p. 135).

Sadler, succeeding Ramaprasad (1983), pinpointed that the focus of evaluative aptness was a necessary, albeit not a sufficient condition for improvement within a school system. Sadler (1989) also identified three conditions for effective feedback: (1) knowledge of the standards; (2) comparison of those standards to one's work; and (3) action to close the gap between the two other conditions. None of these were separate processes. General knowledge of educational standards depended upon information about what constitutes significant work in any area and the identification of appropriate criteria related to those standards. Comparing these standards to one's work needed the ability to operationalize or ground the standards about the distinct kind of items judged. This would require the use of models of learning and exemplars of completed work for what a particular standard might mean. Judgments thus needed to be refined in light of constructive feedback from experienced sources.

Students who became proficient in exercising evaluative judgment independently of teachers would have the ability to make decisions that were more informed later in life. Providing the necessary information to students to assist them in calibrating their self-evaluations was only one segment of a more elaborate process in their developing this expertise. Students needed also to learn when not to trust the experiences of others.

Research over the 100 years previous to this writing indicated there could be considerable errors and inconsistencies in tutors' judgments. Notwithstanding this, the readiest surrogate for an expert judge was the person who marked assignments and allocated grades. There might be a difference between analysis (that is, marks) and judgment of what was acceptable or not. Yorke (2007) discussed how, when using judgment, rather than measurement, marker reliability was far higher.

There were extensive studies over an extended period comparing students' marks with those of educators (Dochy et al., 1999; Boud & Falchikov, 1989). Subsequent studies showed that students were impartial judges of self-grading. Accuracy of judgment changed according to student experience and course rigor. More rigorous students were more likely to give out lower self-grades, whereas students who were educationally weaker seem to overestimate. As Ward, Gruppen, and Regehr (2002) indicated, however, there were many weaknesses in such studies.

Urban School Settings

Urban public school leaders often insisted that education was the road to a person's moving into the middle class, but for children struggling to escape the grip of poverty there was little hope (Wirt et al., 2004). Learning opportunities at such schools were generally inferior to those at suburban schools. For example, mathematics classes in high-poverty high schools were, twice as likely, taught by a teacher with a credential in a discipline other than mathematics (Wirt et al., 2004). Similarly, science classes at high-poverty high schools were, three times as likely, taught by an instructor with a credential in an area other than science (Wirt et al., 2004).

Besides this problem of certification, teachers in high-poverty schools often reported having to work with outdated textbooks in short supply, obsolete computers and other kinds of technology, and inadequate or nonexistent science equipment (Lewis et al., 2000). In addition, the number of college preparatory or advanced placement offerings lagged significantly behind those at schools serving more advantaged populations (Freel, 1998). When combined, these problems can diminish student engagement and achievement. Thus, conditions in high-poverty schools too often rendered them sites of developmental risk (Evans & Kim, 2013).

When schools provided adequate resources, all students could develop academically as they explore their intellectual abilities. Making laptops available to urban adolescents, for example, increased achievement (Penuel, 2006). A reform initiative that provided wireless access in an urban high school (Project Hiller) enhanced standardized test scores, student motivation, and technological literacy for adolescents in the eighth and ninth grades (Light, McDermott, & Honey, 2002). An innovative project to teach physics to urban high school students using video technology developed their sense of agency in a subject too often closed to low-income urban students (Elmesky, 2005). Substandard curricula and facilities abounded in high-poverty schools, but even relatively modest improvements brought demonstrated benefits to all students' development.

How can public policy surmount the many barriers to high-quality education for all children? Building state-of-the-art public schools with cutting-edge technology to serve the poorest children was a challenging prescription in an era of declining public resources and contested political priorities. One evidence-based but controversial policy initiative to remove structural barriers to educational achievement would supplement the income of poor parents by either raising the minimum wage to a 'living wage' or increasing the Earned Income Tax Credit. Rather than addressing issues of the school plant or academic programs, this initiative was grounded in the belief that families can support student achievement if they can lift their vision from a daily struggle for survival. Recent analysis by Dahl and Lochner (2005) concluded that direct cash supplements to family income had a causal relationship to student achievement, and that these relationships were strongest for the poorest families and female-headed households.

Another important policy initiative discussed in President Obama's 2013 State of the Union Address and subsequent speeches was investment in early childhood education. The evidence was plain that high-quality early childhood education led to intellectual and academic gains in the short run, as well as to long-term improvement (sleeper effects) in life chances for poor children (Knudson, Heckman, Cameron, & Shonkoff, 2006). Working to 'compensate' for pervasive disadvantage as K-12 students progress may be too late for the poorest children to breach the barriers that separated them from advantaged students who had enjoyed enriched environments since birth.

A final, and perhaps most controversial, policy initiative might consider how to encourage more effective teachers to work in high-poverty schools. The questions of teacher assignments, merit pay, and evaluations based on student test scores were fraught with dissent across the political spectrum. However, it was undeniable that the most qualified teachers were not found in high-poverty schools.

All of these possible initiatives required the right combination of funding and political will. California had a discussion worth watching as its state legislature and governor took cautious steps toward a new school funding formula. In 2012, voters in California approved a tax increase that could provide schools and districts, particularly those serving high-poverty communities, with additional funding to equalize per-pupil expenditures across the state. New money might allow districts to enact policy initiatives and structural reforms. This revised funding formula were still in the very early stages of the political process, so it was unclear exactly what would result for the most vulnerable students in California's public schools. Still, bold moves are called for if public education were to cease being one of the structural determinants of poverty (Hudley, 2013).

Researchers and scholars commonly agreed that environmental factors had a heavy influence on students' performance in academic settings (Noguera, 2003). Although educators cannot alter a student's socioeconomics, genetic predisposition, or ability level, changes in school environment can improve his or her chances of academic success (Lehr, 2004; McEvoy & Welker, 2000). Promoting a positive school climate was often an aim of school-wide initiatives (Griffith, 2000; Koth, Bradshaw, & Leaf, 2008; Novak, Rocca, & DiBiase, 2006; Flay, 2000; Zullig, Koopman, Patton, & Ubbes, 2010). A positive school environment was associated with fewer behavioral and emotional issues for students (Lehr, 2004; Marshall, 2006).

A positive school climate existed when all involved with the whole school system felt not only comfortable but also wanted, accepted, and valued in a secure environment (Mayer, 2007). School settings with a positive atmosphere welcomed the involvement of all stakeholders (Koth et al., 2008; American School Counselor Association, 2003). Research showed a direct connection between school climate and academic achievement (Noguera, 2003), staff morale (Mayer, 2007), and classroom management (Marshall, 2006). Frieberg (1998) asserted that, "School climate can be a clear influence on the status of the learning environment or a substantial barrier to learning" (p. 22).

In the effort to improve a school's environment, the first place to begin was the physical setting. Any part of a school facility that was unpleasant, unattractive, littered, grimy, dusty, or dingy should be ameliorated. According to the Office of Disease Prevention and Health Promotion (2000), a healthy school environment included such things as indoor air quality, pest and chemical management, ventilation, and elimination of mold and moisture issues that may pose risks to students and staff.

In addition to such maintenance issues, school policies should reflect the shared expectations of the entire community, and parents should be apprised of these expectations. Policies reflected the perceptual orientations of the policy-makers. The current study captured some aspects of school policy, such as the willingness of teachers to help students with particular problems, support of students' freedom of expression, the nature of messages or notes sent home, and grading practices. Overall, despite the challenges faced by public schools in urban settings, it was possible through astute policies, programs, processes, and people, to realize positive academic achievement by students.

Urban Students

Many urban and rural high schools had classrooms with an excessive number of students (Anyon, 2006; Hardy, 2005). According to the U.S. Census Bureau's dichotomous division of urban and rural populations, based solely on population density, approximately 81% of Americans were living in urban settings in 2006. Given that most students resided in urban settings, education in science could reach a vast population. However, it was not the number of students but the nature of their community and physical environment that would most likely affect students' reactions to science instruction.

Knowing answers to the following questions was vital to creating and implementing an effective curriculum in urban high schools. What were the students' lives like? What motivated students to come to school? What resources did they bring to the classroom? What challenges might a student face in a public-school environment? The first issue to be addressed was 'Who exactly are urban students?'

America's two largest cities, New York City and Los Angeles, highlighted the diversity of urban populations in the U.S. as a whole. The inner-city schools of these two cities were diverse in their ethnic backgrounds and history. Comparing these two major cities to the national average, a larger percentage of their populations were either foreign-born or first-generation Americans who spoke a language other than English either at home or in their community (U.S. Census Bureau, 2006). Many urban students did not have a linguistic or cultural identity shared by their school peers or instructors. This diversity was one of the largest challenges that an urban instructor faces. However, that same cultural diversity had the potential to be an amazing resource because students brought contextually rich backgrounds to the classroom.

Urban students were more likely than their counterparts elsewhere to have to set aside a large proportion of time to part-time jobs that supported their families' household income. Even though they had limited time for schoolwork beyond the classroom, urban students' sense of responsibility had the potential to be highly motivational. If an educational activity allowed for practical skills and career connections, the urban student will have more of a connection to it (Lippman, McArthur, & Burns, (1996).

Casserly, director of the Council of the Great City Schools, discussed urban demographics with regard to science learning, “The poverty that pupils in an urban setting have to overcome will work [. . .] like a perfect storm to wash down results [in science education] in a way that few others school settings have to contend with” (as cited in Schemo, 2006, p. A1). He was responding to a NAEP report that academic performance in urban public schools was well below the national average. In nine out of 10 major cities that participated in the study, more than half of eighth-grade pupils failed to demonstrate a basic knowledge of science (Lutkus et al., 2006). This finding was associated with issues of race and wages in urban population centers. Grigg, Daane, Jin, and Campbell (2003) documented that Black and Hispanic students scored much lower than White and Asian students did on standardized science tests in the senior year of high school.

In light of these test results, it was interesting that Shepardson, Wee, Priddy, and Harbor (2007) found urban students required an urban context in order to integrate new knowledge from classroom learning. Urban students’ isolation from a natural environment was recognized by d’Alessio (2008) in a survey of his Bay Area classes. Of those urban students, 8% had never been to the ocean despite its being less than 15 miles from the school. He also reported that less than 50% considered their room or home to be their favorite location away from school.

The disconnection between how urban students saw school-based endeavors and their everyday life in local communities was a barrier to learning. For many working-class families unaccustomed to American educational norms, the school setting was commonly thought of as being “in the association, but not of the local association” (Bouillion & Gomez, 2001, p. 878). This point indicated that identifying that with students in ethnically and linguistically disparate urban locations was a challenge, especially if instructors did not understand their students' priorities, perspectives, and cultural lenses. To teach productively in an urban classroom, teachers must analyze and infer their students' cultural assets (Roth et al., 2001). Science teachers in particular must ground their instruction in the urban experiences of their students (Hammond, 2001).

Researchers who honed in on urban, minority, and poor students, commonly called back on the 'funds of knowledge' statement. This statement told students to bring to the classroom the best that had been taught to them (Hammond, 2001). The 'funds of knowledge' were skills and knowledge that developed historically and culturally, to empower an individual or household to function within a given culture (Moll, Amanti, Neff, & Gonzalez, 1992). It was the knowledge that was useful and transferable to everyday life, and it provided a path to students for actions as they tried to achieve their objective in their 'out-of-school' existence (Basu & Barton, 2007). An example, from Basu and Barton (2007) talked about the life of a young student of a Latino carpenter. This student might be more proficient at practical quantitative skills such as measurement and conversion, and may be responsible for the reading of complex documents related to the family environment such as medical and legal documents.

Cultural viewpoints strongly shaped a child's view of acquired knowledge and new skills. If urban students perceived a lesson as enabling them to control their life, not only in the local community but also in the larger world, they were likely to welcome related information and learned skills (Bouillion & Gomez, 2001). Vierling, Bolman, & Lane, (2005) reported improvement in science education for Native American students by connecting the focus of learning to their cultural context. If a curriculum was not student-centered in this respect, urban students were likely to view the experience as “not real to them” (Fusco, 2001, p. 870).

A curriculum that involved urban students’ local communities and/or families will engage their interest (Fusco, 2001). A connection to community was only possible through an awareness of coordinated and culturally sensitive learning opportunities over the entire span of high school. Engagement of the urban family can help the parents of a first-generation student discover the advantages of post-secondary education for their child and his or her future career options. Every town had some community-based organizations such as historical societies and environmental programs. Service-learning internships with local community organizations can yield educational benefits to minority students, since such partnerships provided culturally matched mentors for students in those environments.

Summary

Considerable research was devoted to hands-on science, urban schools, and poverty in the U.S. educational system. Chapter Two reviewed researchers’ studies of these and related topics. Science literacy had a foothold in American classrooms, thanks largely to NGSS, which advanced the cause of hands-on learning for all populations of students. The inquiry selections of NGSS were nothing, if not mold breaking, in the way in which they prompted students to think deeply about a concept and find connections between what was learned and what would be accomplished.

Chapter Three describes the methodologies used in this study. Chapter Four presents results, and the final chapter offers conclusions and recommendations for further study.

Chapter Three: Methodology

Introduction

Chapter Three explains the research study methodology and data-collection process, including the surveys (quantitative) and, pre and post-questionnaires (qualitative) on which it relied. The project investigated the use of entomological research with secondary students in the Midwest to promote hands-on science inquiry in a high-poverty urban setting.

Overview

The researcher chose a mixed-method, action research approach for several compelling reasons. In general, mixed-method studies aggregate data, analyze findings, and combine both qualitative and quantitative data (Ivankova, 2002; Mills, 2003). Participants were purposefully selected and involved in use of the sampling tools of the survey and interviews, audio-recorded by a third party, and focus groups again led by a third party. Though originally planned, the focus group meetings were, in the end, not carried out in this action-research study. The third party member was a science coordinator for the Midwestern school where the study took place.

The study gathered three sources of data and used the following procedures to support the research design.

Instrument development: The researcher created a survey instrument grounded in the literature review. A pilot survey tool was created for this study and was designed to be used in any type of science research related to a specified content. The survey created for this study focused on the content of entomology, and was research-based on previous entomological education research by Golick, Heng-Moss, & Ellis (2010). In future studies, the wording of the survey could be interchanged from with topics from different science content. For example, entomology could be exchanged with the term chemistry. This research study was set up on a small scale, with the possibility of future major study on the use of entomology and research across a full school district. Polit, Beck, and Hungler (2001) said, “A pilot study can be arranged as a small scale setup of a major study” (p. 467).

In a pilot survey was administered to participants in a similar program, the researcher changed the survey based on responses of participants in the pilot survey. The survey instrument was validated by a second online pilot survey administered to the same group. In comparison of the original survey and the revised survey following the pilot study, the introduction of the entomological terminology, how to properly find research, and the activity was used to help the students with entomology were changed. Once the assigned research topic was located by the student, the student had to break it down to support the findings resulting from the activity or disprove what was first conceived at the beginning of the study. The validity of the revised pilot survey came in the form of content validity. The content of the study was found to be a match between the survey questions and the content being assess in the study (Haynes, Richard, & Kubany, 1995).

Examine multiple levels: Following a nested model (Creswell, 2002), the researcher collected survey data and then conducted interviews to explore the responses of specific individuals. A nested model was typically used to help in the explanation of qualitative results and reinforce the quantitative results of the research study (Creswell, 2002).

The pre and post-surveys, as well as the pre and post-questionnaires, were created to view discussion of the students’ answers from beginning-to-end of the testing lesson.

The surveys provided the foundational data for this study. The student survey answers were used to make a profile for comparing to the parts of the action research that emerged from the literature review, discussed in Chapter Two.

Thirty students volunteered, with their parents' or guardians' permission. Interviews with 10 of these students were completed by the third party, involved in this experiment, in order to reduce bias on the part of the researcher. While surveys and questionnaires provided valuable information, the researcher needed to examine students' responses closely and correlate them, in order to draw conclusions from the two other sources of data. This combination of quantitative and qualitative data provided insight into the matter under investigation.

Null Hypothesis

H1o: Following participation in the hands-on entomological research science unit, students will exhibit a difference in understanding of science concepts, measured by a comparison of pre-to-post Survey Questions (# 3, 5, 8, and 9).

H2o: Following participation in the hands-on entomological research science unit, students will exhibit a difference in perceptions and attitudes concerning science, measured by a comparison of pre-to-post Survey Questions (# 1, 2, 3, 4, 6, 7), and 10.

Research Questions

RQ 1: How does hands-on science affect students' perspective on learning?

RQ 2: How does hands-on science affect students' understanding of concepts?

RQ 3: How can using research in a science class improve hands-on education?

RQ 4: How does using entomological research contribute to improving science education?

RQ 5: How can entomological research improve high-poverty students' learning science?

This study can best be described as action research. The study was based on a sample size of 30 students, local participants and their experiences during the inquiry curriculum unit. Fraenkel, Wallen, and Hyun (2012) defined action research as research "conducted by one or more individuals or groups for the purpose of solving a problem or obtaining information in order to inform local practice" (p. 589). This study can only make claims about the population studied. It is not sound use of these research results to lead to the assumption that other people would have the same responses.

Because the sample size was small (n = 30), the data-collection tools used were specifically developed for this action research study. These tools helped to create the sources from which the researcher pulled sufficient data to examine the hands-on science inquiry process, along with entomological research. Data analysis required the researcher to 'look through a microscope' at the students who participated in the study.

Variables

The independent variable in this investigative study was the use of entomological research in conjunction with the hands-on science model.

The dependent variable was how effective the hands-on model of learning was when implemented with entomological studies.

Activity

The activity participants worked on was the Beetle Race. The purpose of the activity was to describe, measure, and research how far a particular beetle could travel in 30 seconds on three different types of material, marking every five seconds as a different segment traveled. Students then analyzed the data to show the five-second intervals during which the beetle moved either the fastest or the slowest. In addition to this activity, the students researched how the different segments of a beetle's body and legs made a difference.

Activity Procedure

1) Students first worked in groups no larger than four and no fewer than two.
2) Once partners were selected, a member of the group got a petri dish from the teacher.
3) The teacher then distributed materials for completing the laboratory activity. These items were colored pencils in red, blue, and black; a stopwatch; a clear plastic ruler; and a roll of string.
4) The teacher gave each group a mealworm beetle, *Tenebrio molitor*; made some observations of what the beetle looked like; and wrote them down in a laboratory journal.
5) A group member collected from the teacher three different textured styles of paper to take back to the groups. This was the material on which the beetle would move around.
6) Students put an X in the center of each of the three different pieces of paper, marking the starting point of the beetle race.
7) The teacher instructed the students to remove the beetles carefully out of the petri dishes onto the X starting point, making sure the beetles were able to move on their legs and were not on their backs.
8) Once all groups were ready, the teacher instructed the students to use a stopwatch

to measure 30 seconds of time.

9) Before the timed event began, the teacher instructed the students to make sure they marked every five-second interval the beetle traveled**.**
10) The teacher then instructed the students marking the line to make sure they also had a ruler to keep the beetle on the paper surface.
11) The teacher told the students they would use the red pencil to trace the beetle's path on the three different types of paper, followed by the blue, and finally the black pencil.
12) The researcher advised the students of ways to motivate the beetle to move on the paper.
13) The teacher explained that when he said, 'Start,' the student with the stopwatch would begin.
14) The stopwatch student should call out every five seconds to tell the marker when to mark a line on the beetle's path.
15) When the beetle finished the allotted time for the race, one group member would need to put the beetle back into the petri dish until the next race began.
16) The group members were then to draw in their laboratory journals the beetle's course and construct a data chart for distance traveled versus time.
17) Once this activity was completed, the students used the string to measure the exact amount of distance traveled between five-second marks. They then put the string up against the ruler on the centimeter side to measure the distance traveled.
18) This step was completed for each separate trial.
19) Once all trials were completed, students calculated the average speed of the beetle

during each five-second interval. This calculation allowed students to construct a graph to show on which material the beetle traveled faster.

20) The students then transferred the material from their data tables onto a graph for a visual representation of the beetle's speed.

21) Once the laboratory exercise was completed, the teacher had each group bring up the materials used for the experiment, except the beetle and petri dish.

22) The teacher gave a 10X magnifying glass to the students, so they could make closer observations of the beetles and begin constructing research questions regarding how the beetles moved on the different types of paper.

23) The questions the students generated guided the direction of their research assignments.

24) The students had two days of 60-minute class periods to research entomological studies related to the different anatomical structures of beetles, as well as to make connections to how the different structures affected the way a beetle moved.

25) Once the two days of research were completed, students presented their findings from the races, as well as from their entomological research.

Role of the Researcher

The researcher was an entomologist, as well as a teacher. These two careers were very different in the role they played in the world, but had a large connection in how they interacted in the world of education. Both of these careers made heavy use of the scientific method to understand the world. Both of these fields recognized that with the use of data there could be meaningful conversations about topics and viewpoints that might relate to only a particular part of the world.

Methodology

This study engaged both qualitative and quantitative measures to collect data and record findings (Creswell, 2011). It sought to explore how the hands-on learning model in science could be improved through entomological research. To find out whether there were significant changes in scientific understanding over the timeframe of this study; participants were given pre and post-examinations. The methodology of how the researcher conducted this action research experiment is described below.

1) The researcher Gained permission from the school building administrator to complete the study.
2) The researcher secured parental permission forms from Lindenwood University that explained to parents what would take place if their student participated in the study. Had teachers of courses titled Biology, Biology B, and Honors Biology inform their students of an optional meeting after school.
3) The researcher met after school with students interested in participating in the study.
4) The researcher passed out permission forms for students to take home after the meeting, if they wanted to participate.
5) The researcher allowed the students to return the completed forms to a neutral, third-party adult employee of the Normandy School Collaborative, Normandy High School.
6) The researcher asked the third party to collect assent forms from students and consent forms from parents. She then assigned a code to each participant and recorded it with the student's name. This allowed the third party to extract data

from the lessons that corresponded to the students who assented to participation. The possibility of coercion was, thereby eliminated, because the researcher did not know who was participating and who was not participating in the study, thus protecting participant confidentiality. The researcher advised the third party that she would need to keep the codebook and consent forms in separate locations, secured for three years under federal regulations, and then destroy them.

7) The third party employee of the Normandy School Collaborative, Normandy High School, collected the forms from the students wanting to participate in the study from a locked container accessible only by the third party.
8) The third party counted the number of forms returned of students participating to see if the minimum number of participants was reached.
9) The researcher began the study by having the third party administer a pre-survey to students, before the hands-on entomological experiment began.
10) The third party administered a pre-test to the students.
11) The researcher introduced the hands-on science-inquiry project on beetles to participants and explained that it would last for five-to-ten days.
12) The researcher explained that at the end of five- to-ten days the third party would interview students who volunteered for that stage of the research project and pass out a post-survey to all participants to measure how effective this model of hands-on learning was for students in the study.
13) The researcher explained that the third party would lead an interview of 10 participants in open-ended conversations about the experiment.
14) The third party conducted the interviews.

15) The researcher explained that the third party would administer a post-test to participating students.
16) The end of study for the participants was the completion of the post-test of students.

Participants

The voluntary participants were students at Normandy High School, an urban school in the Midwest, enrolled in Biology, Biology B, and Honors Biology classes. They returned permission forms to a third party in order to reduce the possibility of researcher bias. The students had the ability to withdraw from the research study at any time, if they chose to do so.

Instrumentation

The surveys and questionnaires were administered using Survey Monkey®, a Web-based survey tool. The choice to use Survey Monkey® was based on its ease of use and confidentiality for participants. Students who agreed to participate in the study were provided with an access link that allowed them to be as anonymous as possible.

The survey consisted of 10 statements with five rankings for participants' perceptions of using entomological research in hands-on science. Each of the 10 statements required respondents to use a Likert scale to rate the strength of agreement or disagreement with the statement. The Likert ratings were Strongly Disagree, Somewhat Disagree, Sometimes, Somewhat Agree, and Strongly Agree. Each survey statement was followed by a question asking the participant to explain his or her rating and to provide an example to illustrate the score. The ratings for the 10 survey statements were tallied, based on grouping Strongly Agree and Somewhat Agree as a positive perception and therefore, in support of the alternative hypothesis. The ratings Strongly Disagree, Somewhat Disagree, and Sometimes were arranged as a negative perception and therefore, in support of the null hypothesis. The researcher conducted a *z*-test for difference in proportions to determine if a statistically measurable difference existed between positive and negative ratings. The size of the sample raised a possibility that there may be no statistical difference.

Surveys and Coding of Response

The pre and post-surveys were coded for five prominent themes and included the following questions and statements: 1) Do you like insects?; 2) Do you enjoy science?; 3) I feel that I learn better using hands-on options; 4) Science is harder for me than most of my classmates; 5) Have you ever used insects in a science class before?; 6) Is science useful for solving practical problems in life?; 7) Scientific work is interesting; 8) All insects have eight legs?; 9) Have you ever used research in your science class?; and 10) Do you enjoy it when a science teacher lectures?

The survey data were broken down into five different codes, due to the range of questions asked. The five codes were growth, expectation, self-perception, life enhancement, and support. Growth defined as gaining knowledge on a professional as well as personal level. Expectation defined as a belief that one will or should achieve something. Self-perception defined as an individual’s attitudes and preferences by understanding his or her own behavior. Life enhancement defined as an intensified or magnified belief. Support, finally, defined as foundational endurance.

Procedures

The sample size of the study was relatively small (30 students), yet large enough to provide valid comparison, and the statistical measurement deemed appropriate for testing the null hypothesis was a *z*-test for difference in proportions. This test is "used when the population is normally distributed and the population standard deviation is known" (Bluman, 2001, p. 710). When reviewing the results of the responses to the 10 statements, the researcher tallied the results and grouped Strongly Agree and Somewhat Agree in the desirable range, whereas Strongly Disagree, Somewhat Disagree, and Sometimes fell into the undesirable range. The *z*-test for difference in proportion was used to determine whether there was a statistically significant difference between the two ranges.

To test for the null hypothesis, the critical value for the *z*-test was set at ±1.96, appropriate for an alpha-value of 0.05, representing a 95% confidence level in the results of the study. The critical region for the null hypothesis "is the total range of values that shows that there is a significant difference and that the null hypothesis should be rejected" (Bluman, 2001, p. 343). The alpha value was set at 0.05 because that represented a 5% chance that a Type I error would occur. This would then cause the researcher to reject the null hypothesis, when it occurred (Bluman, 2001).

The second part of the survey consisted of open-ended questions linked to the survey statements. "Open-ended questions allow for more individualized responses, but they are sometimes difficult to interpret" (Fraenkel et al., 2012, p. 400). They were used in this study to provide a more detailed picture of how the students viewed hands-on science learning, with the input of entomological research, and how they felt it impacted their learning. Individual replies were analyzed for commonalities, and responses were grouped accordingly.

This mixed-methods action research study employed both quantitative and qualitative measures to investigate the relationship between exciting, steady work designed for student performance and production from the hands-on learning model in science and the use of entomological research. The hands-on science model was the foundation for establishing exciting, purposeful work for the students in the classroom. The effectiveness of the hands-on science model, with entomological research, was measured quantitatively by a survey using Likert scale ratings for measurement of responses. The researcher computed the ratings, based on grouping the amount of agree and strongly agree on ratings as evidence that the hands-on science model using entomological research helped with the students learning. The study employed qualitative measures in the form of answers to open-ended questions, as reported in the Chapter Four. Therefore, the study was a mixed method, in which both qualitative and quantitative data were collected and analyzed to answer a single type of research question. The final inferences based on both data analysis results. Data were to be mutually reinforcing or to have convergent inference meaning, when the data were reviewed to check if the interpretations of the two different strands of a mixed-methods study were parallel with each other.

Summary

This action research study looked at qualitative and quantitative data related to the hands-on activity of a beetle race held in a high school science classroom for purposes of science inquiry. The researcher devoted over five class periods to the completion of this work for participants in the study. A total of 30 high school students (n = 30) and three cooperating biology teachers participated, under instructions from the researcher. The resulting data were analyzed and coded, in such a way as to eliminate the possibility of researcher bias.

The three criteria of credibility, transparency, and confirmability were applied to the entire project from beginning to end. The data that were collected via pre and post-questionnaires, pre and post-surveys, and interview sessions. Chapter Four provides detail about the raw data and the researcher's interpretations thereof.

Chapter Four: Results

Introduction

Chapter Four restates the study's purpose, hypothesis, and research questions. It then presents a quantitative analysis of the results as described in the preceding chapter. Background information on the survey provided first, followed by the questionnaire. The interviews and their connection to the two other forms of data collection correlated with their related findings. Chapter Four ends with an overview of the study's results.

The purpose of this study was to examine the extent to which entomological research could promote hands-on learning of science inquiry in a high-poverty, urban high school.

Research Questions

RQ 1: How does hands-on science affect students' perspective on learning?

RQ 2: How does hands-on science affect students' understanding of concepts?

RQ 3: How can using research in a science class improve hands-on education?

RQ 4: How does using entomological research contribute to improving science education?

RQ 5: How can entomological research improve high-poverty students' learning science?

Three themes run through these research questions: hands-on learning, research, and urban students.

Chapter Four presents the findings from the collected data. Quotations from the participants, gathered from surveys and interviews, will accompany the data in order to illustrate whether the students' learning changed from the beginning of the study to its conclusion.

Null Hypotheses

H1o: Following participation in the hands-on entomological research science unit, students will not exhibit a difference in understanding of science concepts, measured by a comparison of pre-to-post Survey Questions (# 3, 5, 8, and 9).

H2o: Following participation in the hands-on entomological research science unit, students will not exhibit a difference in perceptions and attitudes concerning science, measured by a comparison of pre-to-post Survey Questions (# 1, 2, 3, 4, 6, 7), and 10.

Data Management

All data were coded by Greek upper and lower-case symbols to protect the anonymity of students who participated in the research. The researcher maintained separate folders for each student's work completed during the study. A professional transcriber transcribed the recordings, and they were stored in a secure place. The researcher coded the notes taken during the project and gave them to the assistant. These notes helped the researcher draw connections between the qualitative and quantitative data.

Survey Timeframe and Results

On November 12, 2015, the researcher distributed a letter (Appendix B) to biology students at Normandy High School who were taking a biology or honors biology course at the high school. Each respondent then met with the researcher, who explained the study and gave parental permission forms to students interested in participating. Within four days, a minimum number of volunteers agreed to participate in the study.

When the researcher began the process of data collection, 30 students had agreed to complete the online pre-survey questionnaire.

Results of the Pre-Survey

Pre-survey findings were reported in three parts, corresponding to the different themes identified in the literature review concerning hands-on learning, research, and urban students. The response answers on the pre-survey were reported in the form of a Likert scale. The researcher assigned values to the category options for responses on a one-to-five scale. All students in the study responded to 10 questions. The pre-survey findings reported provide background information on the participants.

Background Information on Participants in the Study

The 30 urban students who participated in this study were biology students at Normandy High School. To reduce possible bias, because the researcher taught at the same school, participants were not identified by name in all documentation related to the project.

Quantitative Data

The Null Hypotheses, $H_{0,}$ for this study are as follows:

H1o: Following participation in the hands-on entomological research science unit, students will not exhibit a difference in understanding of science concepts, measured by a comparison of pre-to-post Survey Questions (# 3, 5, 8, and 9).

H2o: Following participation in the hands-on entomological research science unit, students will not exhibit a difference in perceptions and attitudes concerning science, measured by a comparison of pre-to-post Survey Questions (# 1, 2, 3, 4, 6, 7), and 10.

Quantitative data collected on the responses to 10 survey statements. Participants responded either positively (Strongly Agree or Somewhat Agree) or negatively (Strongly Disagree, Somewhat Disagree, or Sometimes). Positive responses considered supportive of the pre-survey statement and negative responses considered supportive of disagreement with the pre-survey statement. The pre-survey statements and results of the z-test for difference in proportion between positive responses and negative responses were:

1) Do you like insects?

Table 1

Results of z-Test for Pre-Question 1

Statistical Test	Results
z-test value	2.74
z-critical values	±1.96

There were six positive and 24 negative responses. Since the *z*-value of 2.74 was larger than the critical value of +1.96, it falls within the critical region. Therefore, the researcher rejected the null hypothesis and supported the alternative hypothesis that there is a difference. There was a statistical difference between the positive and negative response rates, with the answer to this question statistically leaning toward negative. Students felt they did not like insects.

2) Do you enjoy science?

Table 2

Results of z-Test for Pre-Question 2

Statistical Test	Results
z-test value	6.71
z-critical values	±1.96

There were 18 positive and 12 negative responses. Since the *z*-value of 6.71 was larger than the critical value of +1.96, it falls within the critical region. Therefore, the researcher rejected the null hypothesis and supported the alternative hypothesis that there is a difference. There was a statistical difference between the positive and negative response rates, with the answer to this question statistically leaning toward positive. Students agreed with the statement that they hey enjoyed science.

3) I feel that I learn better using hands-on options.

Table 3

Results of z-Test for Pre-Question 3

Statistical Test	Results
z-test value	9.93
z-critical values	±1.96

There were 23 positive and 7 negative responses. Since the *z*-value of 9.93 was larger than the critical value of +1.96, it falls within the critical region. Therefore, the researcher rejected the null hypothesis and supported the alternative hypothesis that there is a difference. There was a statistical difference between the positive and negative response rates, with the answer to this question statistically leaning toward positive. Students agreed with the statement that they learned better using hands-on options.

4) Science is harder for me than most of my classmates.

Table 4

Results of z-Test for Pre-Question 4

Statistical Test	Results
z-test value	2.15
z-critical values	±1.96

There were four positive and 26 negative responses. Since the *z*-value of 2.15 was larger than the critical value of ±1.96, it falls within the critical region. Therefore, the researcher rejected the null hypothesis and supported the alternative hypothesis that there is a difference. There was a statistical difference between the positive and negative response rates, with the answer to this question statistically leaning toward negative. Students disagreed with the statement that science was harder for them than most of their classmates

5) Have you ever used insects in a science class before?

Table 5

Results of z-Test for Pre-Question 5

Statistical Test	Results
z-test value	3.02
z-critical values	±1.96

There were seven positive and 23 negative responses. Since the *z*-value of 3.02 was larger than the critical value of ±1.96, it falls within the critical region. Therefore, the researcher rejected the null hypothesis and supported the alternative hypothesis that there is a difference. There was a statistical difference between the positive and negative response rates, with the answer to this question statistically leaning toward negative. Students disagreed with the statement that they had used insects in a science class before.

6) Is science useful for solving practical problems in life?

Table 6

Results of z-Test for Pre-Question 6

Statistical Test	Results
z-test value	5.12
z-critical values	±1.96

There were 14 positive and 16 negative responses. Since the *z*-value of 5.12 was larger than the critical value of ±1.96, it falls within the critical region. Therefore, the researcher rejected the null hypothesis and supported the alternative hypothesis that there is a difference. There was a statistical difference between the positive and negative response rates, with the answer to this question statistically leaning toward negative. Students disagreed with the statement that science was useful for solving practical problems in life.

7) Scientific work is interesting.

Table 7

Results of z-Test for Pre-Question 7

Statistical Test	Results
z-test value	7.75
z-critical values	±1.96

There were 20 positive and 10 negative responses. Since the *z*-value of 7.75 was larger than the critical value of ±1.96, it falls within the critical region. Therefore, the researcher rejected the null hypothesis and supported the alternative hypothesis that there is a difference. There is a statistical difference between the positive and negative response rates, with the answer to this question statistically leaning toward positive. Students agreed with the statement that science was interesting.

8) All insects have eight legs.

Table 8

Results of z-Test for Pre-Question 8

Statistical Test	Results
z-test value	29.50
z-critical values	±1.96

There were 29 positive responses and 1 negative response. Since the *z*-value of 29.50 was larger than the critical value of ±1.96, it falls within the critical region. Therefore, the researcher rejected the null hypothesis and supported the alternative hypothesis that there is a difference. There was a statistical difference between the positive and negative response rates, with the answer to this question statistically leaning toward positive. Students agreed with the statement that all insects have eight legs.

9) Have you ever used research in your science class?

Table 9

Results of z-Test for Pre-Question 9

Statistical Test	Results
z-test value	6.71
z-critical values	±1.96

There were 18 positive and 12 negative responses. Since the *z*-value of 6.71 was larger than the critical value of ±1.96, it falls within the critical region. Therefore, the researcher rejected the null hypothesis and supported the alternative hypothesis that there is a difference. There was a statistical difference between the positive and negative response rates, with the answer to this question statistically leaning toward positive. Students agreed with the statement that they had used research in science class.

10) Do you enjoy it when a science teacher lectures?

Table 10

Results of z-Test for Pre-Question 10

Statistical Test	Results
z-test value	1.02
z-critical values	±1.96

There were 1 positive and 29 negative responses. Because the *z*-value of 1.02 was smaller than the critical value of ±1.96, it did not fall within the critical region. Therefore, the researcher did not reject the null hypothesis and did not support the alternative hypothesis that there is a difference. There was not a statistical difference between the positive and negative response rates.

Results of the Post-Survey

The post-survey results reported in a range of possible answers. Participants responded either positively (Strongly Agree and Somewhat Agree) or negatively (Strongly Disagree, Somewhat Disagree, and Sometimes). Positive responses considered supportive of the researcher's claim that the hands-on science learning approach would make a difference in student perceptions and achievement. The post-survey statements and results of the *z*-test for difference in proportion between positive responses and negative responses were:

1) Do you like insects?

Table 11

Results of z-Test for Post-Question 1

Statistical Test	Results
z-test value	4.79
z-critical values	±1.96

There were 13 positive and 17 negative responses. Since the *z*-value of 4.79 was larger than the critical value of ±1.96, it fell within the critical region. Therefore, the researcher rejected the null hypothesis and supported the alternative hypothesis that there is a difference. There was a statistical difference between the positive and negative response rates, with the answer to this question statistically leaning toward negative. Students felt they did not like insects.

2) Do you enjoy science?

Table 12

Results of z-Test for Post-Question 2

Statistical Test	Results
z-test value	6.71
z-critical values	±1.96

There were 18 positive and 12 negative responses. Since the *z*-value of 6.71 was larger than the critical value of ±1.96, it fell within the critical region. Therefore, the researcher rejected the null hypothesis and supported the alternative hypothesis that there is a difference. There was a statistical difference between the positive and negative response rates, with the answer to this question statistically leaning toward positive. Students agreed with the statement that they enjoyed science.

3) I feel that I learn better using hands-on options.

Table 13

Results of z-Test for Post Question 3

Statistical Test	Results
z-test value	7.20
z-critical values	±1.96

There were 19 positive and 11 negative responses. Since the *z*-value of 7.20 was larger than the critical value of ±1.96, it fell within the critical region. Therefore, the researcher rejected the null hypothesis and supported the alternative hypothesis that there is a difference. There was a statistical difference between the positive and negative response rates, with the answer to this question statistically leaning toward positive. Students agreed with the statement that they learn better using hands-on options.

4) Science is harder for me than most of my classmates.

Table 14

Results of z-test for Post-Question 4

Statistical Test	Results
z-test value	1.83
z-critical values	±1.96

There were 3 positive and 27 negative responses. Because the *z*-value of 1.83 was smaller than the critical value of ±1.96, it did not fall within the critical region. Therefore, the researcher did not reject the null hypothesis and did not support the alternative hypothesis that there is a difference. There was not a statistical difference between the positive and negative response rates.

5) Have you ever used insects in a science class before?

Table 15

Results for z-Test for Post-Question 5

Statistical Test	Results
z-test value	29.50
z-critical values	±1.96

There were 29 positive responses and 1 negative response. Since the *z*-value of 29.50 was larger than the critical value of ±1.96, it fell within the critical region. Therefore, the researcher rejected the null hypothesis and supported the alternative hypothesis that there is a difference. There was a statistical difference between the positive and negative response rates, with the answer to this question statistically leaning toward positive. Students agreed with the statement that they had used insects in science class.

6) Is science useful for solving practical problems in life?

Table 16

Results for z-Test for Post-Question 6

Statistical Test	Results
z-test value	10.95
z-critical values	±1.96

There were 24 positive and 6 negative responses. Since the *z*-value of 10.95 was larger than the critical value of ±1.96, it fell within the critical region. Therefore, the researcher rejected the null hypothesis and supported the alternative hypothesis that there is a difference. There was a statistical difference between the positive and negative response rates, with the answer to this question statistically leaning toward positive. Students agreed with the statement that science was useful for solving practical problems in life.

7) Scientific work is interesting.

Table 17

Results for z-Test for Post-Question 7

Statistical Test	Results
z-test value	29.50
z-critical values	±1.96

There were 29 positive responses and 1 negative responses. Since the *z*-value of 29.50 was larger than the critical value of ±1.96, it fell within the critical region. Therefore, the researcher rejected the null hypothesis and supported the alternative hypothesis that there is a difference. There was a statistical difference between the positive and negative response rates, with the answer to this question statistically leaning toward positive. Students agreed with the statement that science work is interesting.

8) All insects have eight legs?

Table 18

Results for z-Test for Post-Question 8

Statistical Test	Results
z-test value	29.50
z-critical values	±1.96

There were 29 positive responses and 1 negative responses. Since the *z*-value of 29.50 was larger than the critical value of ±1.96, it fell within the critical region. Therefore, the researcher rejected the null hypothesis and supported the alternative hypothesis that there is a difference. There was a statistical difference between the positive and negative response rates, with the answer to this question statistically leaning toward positive. Students agreed with the statement that all insects have eight legs.

9) Have you ever used research in your science class?

Table 19

Results for z-Test for Post-Question 9

Statistical Test	Results
z-test value	29.50
z-critical values	±1.96

There were 29 positive responses and 1 negative response. Since the *z*-value of 29.50 was larger than the critical value of ±1.96, it fell within the critical region. Therefore, the researcher rejected the null hypothesis and supported the alternative hypothesis that there is a difference. There was a statistical difference between the positive and negative response rates, with the answer to this question statistically leaning toward positive. Students agreed with the statement that they had used research in science class.

10) Do you enjoy it when a science teacher lectures?

Table 20

Results for z-Test for Post-Question 10

Statistical Test	Results
z-test value	1.02
z-critical values	±1.96

There were 1 positive and 29 negative responses. Because the *z*-value of 1.02 was smaller than the critical value of ±1.96, it did not fall within the critical region. Therefore, the researcher did not reject the null hypothesis and did not support the alternative hypothesis that there is a difference. There was not a statistical difference between the positive and negative response rates.

Quantitative Results

After reviewing the results of the questions the researcher asked, results indicated an increase in positive agreement on five of the 10 questions from the pre to the post-surveys. Each of the five questions indicated positive agreement with the question statement and showed statistical differences between the percent of students answering with positive agreement and those answering in the negative.

The first question of the pre and post-survey indicating an increase in significant positive agreement with the statement was # 1, asking ‘Do you like insects?’ There was a 23.33% increase in the number of students indicating that they like insects, when comparing the pre-survey results to the post-survey. This was significant growth of the students’ engagement with their overall like of insects.

Question # 5 asked, ‘Have you ever used insects in a science class before?’ Comparison of the pre-survey to the post-survey indicated a 73.33% increase in the proportion of students indicating use of insects in a science class. This response showed the students making connections with the actual insect and the term insects.

Question # 6 from the pre and post-surveys asked, ‘Is science useful for solving practical problems in life?’ and showed a change in positive response of 33.33%. This data from the pre-to-the-post survey showed the researcher that the students in the study have made a connection of being able to use science to solve practical problems in life.

Again, there was growth in positive response with Question # 7, which asked for a response to the statement, ‘Scientific work is interesting.’ There was an increase in positive response of 30.00%. This tells the researcher that the students were making the connection that scientific work was interesting.

The final comparison from the pre-to-post surveys came from Question # 9, which asked ‘Have you ever used research in your science class?’ The change in positive response was 36.66%. This explained to the researcher that students in the study were able to connect to using research in the science classroom.

Qualitative Data and Results

After each of the surveys were completed, participants given a pre and post-research questionnaire that allowed them to elaborate on the pre and post-survey questions. A questionnaire accompanied each pre and post-survey, allowing participants to explain their understanding of the statement questions and the ratings they gave. Nine questions were asked, one following each survey statement, except for Question # 8, which was ‘All insects have eight legs?’ Responses to the nine questions summarized, according to the themes specified in Chapter Three. Quotations from the participants illustrate connections to the study’s hypothesis, and are shared in the following sections.

The Codes

The data were broken down into five different codes, due to the range of questions asked. The five codes were growth, expectation, self-perception, life enhancement, and support. Growth defined as gaining knowledge on a professional as well as personal level. Expectation defined as a belief that one will or should achieve something. Self-perception defined as an individual's attitudes and preferences by understanding his or her own behavior. Life enhancement defined as an intensified or magnified belief. Support, finally, defined as foundational endurance.

Pre-Questionnaire

After providing their answers on the pre-survey, participants were allowed to expand on their responses. This was a way for the researcher to understand how participants were interpreting questions. Student # 1 told the researcher that he could not identify a bug by its shape. Student # 2 reinforced this answer by stating that a bug has eight legs (B 1.2). Other individuals in the research study answered questions related to question number one similarly. The researcher concluded that, on this first question regarding growth, there was much room for change over the course of the study.

For the second code of expectations for Question #1, the researcher found three different paths of possible answers by participants. The first dealt with, 'I do not know anything about bugs;' 'If I know about the bug, it may be safer;' and 'I do not want to know anything about insects' (B 1.2). These three expectations rang true throughout most of the answers, indicating that some students in the study might have been hesitant, but still were interested in conducting the research. This idea also held true for the third code dealing with self-perception (B 1.3).

For the fourth and fifth codes, responses to the first question showed that students were stepping away from this three-path idea and toward positive, negative, or neutral choices. It was in the coding process for the first question that the researcher noticed positive explanations related to having ‘fun in the classroom’ (B 1.5). This evidence suggested that life enhancement in a science classroom was linked to having fun (B 1.4).

For Question # 2, the growth statements focused on students getting information either from a book or on changing the process of learning to a hands-on model (B 2.1). Respondents typically mentioned expectations of things ‘being too hard for learning,’ or they answered, ‘I don’t care’ (B 2.2). For the third coding dealing with self-perception, one of the strongest comments was, ‘My hypothesis is my guess from what I see’ (B 2.3), a comment that showed true self-understanding. On the other side of that coin, when asked how hands-on science affected their understanding of concepts, participants were in the dark when they answered, ‘I don’t know’ and ‘Huh’ (B 2.4). The best responses came from Student # 10, 17, and 23 who said, ‘Hands-on helps me learn’ (B 2.5), an opinion echoed by all but Student # 27 who answered, ‘I like it when the teacher lectures’ (B 2.5).

For Question # 3, pertaining to how using research projects in class may improve science educations and contribute to personal growth, answers tended to be along the lines of ‘I don’t know’ (B 3.1). This was expected from what the researcher found in the survey data. In terms of the code for expectations, Student # 12 replied, ‘Research helps me learn from smarter people,’ but Student # 25 said, ‘Research doesn’t help anyone’ (B 3.2). A positive expectation was reinforced by Student # 20’s explanation, ‘Research helps me feel important and that I am learning’ (B 3.3). Responses by Students # 15 and

27, ‘Science is dependable and everywhere’ (B 3.5), showed an understanding that research improves science education.

In response to Question # 4, all the students answered, ‘I do not know’ (B 4.1). This was not unexpected, since they had not previously been exposed to using entomological research in science classes. As related to the code of expectations, Student # 7 remarked, ‘Bugs are gros[s],’ but Student # 18 wrote, ‘Insects are cool’ (B 4.2). These two statements were typical. In terms of self-perception, Student # 9 said, ‘I don’t want a bug by me,’ but Student # 19 offered a glimmer of hope by asking, ‘What can bugs do for us?’ (B 4.4).

The last research question, RQ 5**,** concerned how entomological research can improve students’ learning of science. In terms of the code for expectations, students sided either with the view, ‘Research means work, [and] I don’t like work’ or the realization that ‘Bugs can help me in science [because] they are everywhere’ (B 5.2). Both statements showed that the students’ expectations were already in place, before they even began the research project. In terms of self-perception, Student # 7 responded, ‘You could get questions answered if you classify them. . . . Sometimes you don’t have questions based on what you want to know.’ On the other hand, Student # 15 said that entomological research is just ‘the stuff around stuff’ (B 5.3). For the coding of life enhancement, Student # 9 gave an intriguing response: ‘Umm, I put down the stuff where you take something out of where it belongs. It ruins what you are learning’ (B 5.4). In relation to the final code of support, Student # 21 responded, ‘Because you don’t know if they [bugs] are really peaceful because it doesn’t say that they are peaceful or there isn’t any information that they are peaceful’ (B 5.5). This statement indicated to the researcher that connections might possibly be made to responses on the post-questionnaire.

Post-Questionnaire

After completing the post-survey, participants were allowed to expand on their answers. This was a way for the researcher to understand participants' responses to survey questions after completing the entomological experiment. Student # 1 said he could now identify a bug by its shape, and Student # 2 reinforced the answer by saying that a bug has six legs (C 1.1), not eight as he originally thought. For the code of expectations related to Question # 1, the researcher found that the study's participants had acquired a rudimentary understanding of scientific inquiry. Student # 22 said, 'I feel that I understand science inquiry much better. It means to me that if I have a question, then I can ask it' (C 1.2). One student stated:

> I ask a question, do background research, construct a[n] hypothesis, analyze data, and draw conclusions . . . Scientific inquiry from my understanding is when the real-world activities are related to science. What it means to me is that many insects from the outside world can be used for different science experiments' (C 1.2).

This motif surfaced in most of the other post-questionnaire responses, indicating a positive change. Student # 3, for example, remarked, 'My current understanding in science inquiry is ok, but I feel like I can do better' (C 1.3).

With regard to the fourth and fifth codes, Student # 7 said, 'Insects have antennae. So do phones. So that's communication' (C 1.4). His comment was reinforced by Student # 12's new interest in 'learning everything because there is so much [in the world]' (C 1.5).

For Question # 2 the statements pertaining to growth focused on students' gaining knowledge from information by, as Student # 8 said, 'Paying attention and staying focused on the object.' Student # 29 reinforced this idea by remarking, 'The most challenging aspect might be the listening and getting of information' (C 2.1). These comments suggested that the participants were learning from the classroom experiment. The students' expectations were grounded on the idea that '[There] is no challenge if you are [simply] following the instructions of the science teacher' (C 2.2). For the third code dealing with self-perception, one of the strongest points was Student # 9's observation: 'I learned that connections are the most important part of science.' Student # 12 agreed by saying, 'I think I will learn . . . and get a new understanding' (C 2.3). Such self-focused answers show significant growth beyond what these students had expressed earlier.

The same was true in relation to the code of life enhancement. Students # 11 and 13 claimed they learned 'an insect's natural habitat is like its own home' (C 2.4). Perhaps the best answer, again, came from Students # 10, 17, and 23, 'Hands-on science gives me an ability to learn what they [insects] do' (C 2.5).

The post-questionnaire answers to Question # 3 provided clear evidence of growth resulting from participation in the study. 'Research,' remarked Students # 22 and 24, 'helped my group understand the insects better' (C 3.1). The researcher was expecting this response from the data collected. Student # 25 wrote, 'Research does help a lot of people' (C 3.2), and Student # 20 explained, 'research helps me feel . . . that I am learning' (C 3.3). Said Student # 15, 'The [beetle] race made me learn about how surfaces matter' (C 3.5).

For Question # 4, with respect to growth, there was a change in answers, especially by Students # 7, 12, 16, and 24. Rather than 'I don't know' (B 4.1), they now admitted, 'The bug research we did show me that science is important' (C 4.1). This change too was expected. In connection with the second code of expectations, Student # 7, who had previously viewed insects as 'gross,' now wrote, 'bugs are neat' (C 4.2). Student # 19 agreed by saying, 'Bugs do a lot for us!' (C4.3).

The last research question, RQ 5**,** concerned how entomological research improves high-poverty urban students' learning science. 'Bugs are everywhere' (B 5.1), student 3 had commented earlier, but now repeating that point he added, 'That is a good thing' (C 5.1). For the research code dealing with expectations, Student # 16 gave this response: 'You can use science at the same time to study one thing . . . Um, like, uh, the bugs we used in science. . . . But it's hard to explain' (C5.2). Student 30 remarked that 'Science doesn't study insects in school. They should. It's cool!' (C 5.2). Both statements show a significant change in outlook. Student # 7 observed, 'Science is different when you use insects because you get to have more fun' (C 5.3). For the coding of life enhancement, student 9 thought of the big picture in connection with entomological research: 'you study . . . global warming, animals . . . and bugs' (C 5.4). For the final code of support, Student # 21, who had earlier wondered whether insects were 'peaceful' now said, 'Bugs rule the world. I see this now [and] what I can learn from them' (C 5.5). This powerful statement proved to the researcher that there was a strong shift for this participant from the pre-questionnaire to the post-questionnaire.

Interview

As stated earlier, some of the participants volunteered to complete the interview session. The interview questions came from the research questions and literature review in this study. All interview subjects were given a pseudonym.

Beetle

Beetle was a traditional high school student. She was not required to participate in the experiment, but she chose to do so. Beetle was a repeat student of the biology course in this Midwestern school district. Beetle described many experiences over her last few years of repeating the biology experiences, with each being a bit different each time. Beetle also took a botany class along with her biology classes. Beetle was very relaxed as the interview conversation began. She indicated her reason for attending this experiment was to become a part of something more while in high school.

‘Actually,’ she said, ‘I have always liked science but, I have never liked living science courses.’ As briefly described above, she was a person who was responsive and responsible, but must be engaged in the topic being taught. The evidence of this lay in her ‘willingness’ to repeatedly take the course and not be put down by not passing, even though it was required to graduate high school. Beetle refused to take an alternative form of the class. She wanted to complete it with her peers.

Particularly, for science, Beetle identified a weakness and, through many experiences realized she was not a science person, but wished that she was one. She felt her first science experience was bad, but this school year Beetle seemed to feel this may be her year in science. Beetle specifically identified her own weaknesses, as well as the difficulties she encountered, as a result of the learning environment she was in. As a learner, Beetle expressed her displeasure with the lack of structure of the previous science lab classes that she had taken.

Prior to this study, Beetle stated she had written a letter to the school principal expressing her frustration and concerns because of one bad experience she had over the last few years. However, Beetle continued to look at her situation at this school in a positive light.

Overall, she felt that 'no particular time was helpful during the experiment . . . it was all helpful.' Beetle ended the interview session by stating that she wished all teachers in the sciences would complete some exercise like what was completed during the study. She made specific recommendations that she felt would enhance the campus tutorial program. Finally, Beetle provided an excellent example of student behavior and determination during the study. She understood it was her responsibility to master the subject material and get the job done the first time, if possible; but, she also felt the school and the teachers could do more to help her succeed. Beetle ended by saying,

> A student won't get it unless you go home and you do it [science] every day - question, repetition, and dedication- you have to understand that it [science] is not something you can go in and do for just a few minutes . . . It has to be every day.

Dragonfly

Dragonfly, was a student in her first time in a biology class. No other records were on file about the student. At the time of the interview**,** Dragonfly had been in the school for four months.

Prior to the interview meeting, Dragonfly spoke many different times regarding her dislike for science as a whole and her dislike for insects in the world. One particular day as the interviewer was leaving school; Dragonfly asked if it was still possible to take part in the study. The interviewer gave her the paperwork and she returned it the next day to the campus.

She stated, ‘I really enjoy being at school, but it is hard to concentrate.’ She went on to say, ‘I have things at home that keep me pulled away from focusing on her school work, and I begin to feel badly about the time I spend trying to make school work.’ Dragonfly struggled with science, and even though it was halfway in the semester, Dragonfly was already beginning to have feelings of doubt about her progress in biology. Dragonfly had only completed one quarter in biology; her first time taking this course; but that semester would be her third or fourth attempted semester in a high school science course. Her high anxiety stemmed from her previous science studies she had attempted before. One of the courses she had completed was in physical science, and Dragonfly said that she almost did not make it.

The biology course at this Midwestern high school was considered, by Dragonfly, to be one of the more difficult she had taken in her high school career, so far. She would like to get her diploma, but realized that she must not only pass her classes, but also learning from the courses was part of that equation of her success. Dragonfly continued by saying,

> The work in the study has been okay. It definitely helps me to at least start my homework and then I can try to finish things at home, but it is hard…this is not my first study that I have been in, but this one has opened my eyes into different things… I have tried several times and just cannot seem to get this science…. [This study] helped me understand the process [of school] . . . I used to go into the [classroom] a lot with blank looks, but it is just not always possible to know what is being taught [cause I do not understand]. It is a little discouraging when I do

> have time and go there and I don't always get my questions answered. The group setting [during the study] is not too bad, but I really need more time…I realize it is a process. I just wish that things will be better and I am not ready to give up. I'm going to give it my best.

Butterfly

Butterfly, attended the public high school in the Midwest, where the study took place. At the time of the interview**,** Butterfly had been in the biology course for a semester.

As the interview began, Butterfly said she had a young son that was born just before school started. She believed her decision to attend high school with her peers and to keep her child would also allow her to balance the life that she wanted to give to her son.

Butterfly had progressed steadily since she began the study. Her attitude was more positive towards the work of science, she was happy to be in school, and she was very excited about her grades and the progress she had made since being in the study. Butterfly said, 'I seem to attract the attention of other students, who want to do well in the classes that I take.' Butterfly said that when she began taking biology this school year, it 'was just over my head.' Because of her desire 'to get on top of it,' she knew she needed help 'in addition to what the teacher was teaching in class.' Once she signed up for this study, Butterfly said, 'I knew I was going to be actually learning science, and it was great! I was just not sure about having to deal with insects. I was going to be there [at the study] every time [according to her life schedule].'

Butterfly soon realized, 'He [the teacher] taught and emphasized a lot of what was on the test… I didn't know the difference between insects was.' Butterfly expressed her experience in the study by saying.

> The interactions with [the teacher] were good. They were hands on science… and if I had a problem, I'd take it and talk to him about it…. He [the teacher] did a lot of work study problems with us . . . he'd present it to us at a different angle or in a different way . . . and gave us little shortcuts on some things and how to . . . figure it out . . . It was intense.

Butterfly also mentioned that having 'others in the [study] who had questions while we were learning was also an added bonus.' Overall, Butterfly received the information she needed and the enjoyment from learning that she was seeking. She worked hard on her own, and she felt that she really did have the 'keys for learning science.' Butterfly added, 'I mean, I think I benefit greatly from being in this study . . . just to get that little extra bonus and understanding of it [science].' Butterfly had progressed through the semester, and she was now more outgoing in her science classes from her own words.

Walking Stick

Walking Stick was a student at the Midwestern school of the study. He entered the school as a traditional high school student with no previous biology course taken at the school, but was currently in one. At the time of the interview, Walking Stick had completed a semester of the biology course.

The interviewer met Walking Stick on the very first day she offered a chance to be in the study. Walking Stick's older, mature side was not at all apparent in his physical appearance. Walking Stick looked very much like a younger student, but spoke as though he was in his college years. Not only was Walking Stick one of the brightest students in the study, but he was also a student who, as he said, ‘thrives in a science classroom.’

He decided to participate in the study because of the topic covered. Walking Stick was highly interested in the ability to work with bugs. He said, ‘I know of bugs, but I bet there is more to know about them.’ Walking Stick told the interviewer he was ‘very excited about this study and trying to get out of it as much as possible.’ Before reaching his goal from the study, Walking Stick would have to master the insect that would be used. He recognized from the first day of the study that he had a lot to learn about science. The focus of the study was not entirely clear to Walking Stick. However, he was able to figure it out, by working with others during the study. He immediately thought, ‘Well, maybe if I take the questions being asked to others, then they would help me out,’ and he continued to say ‘and it did during the study.’ Walking Stick discussed with the interviewer the academic and the personal perspective of what he was leaning during the study. Academically, he found, ‘The whole experience was really nice.’ In addition to the teacher and his methods, Walking Stick also identified the availability of worksheets, videos, and the computer to help him learn more about insects. Walking Stick said, ‘I thought he [the teacher] did a real great job . . . I think you have a better chance of learning something more when [on] a . . . one-on-one basis.’ However, Walking Stick did learn some in a small group setting and said that he thought it ‘was very much a plus because . . . in a much smaller environment . . . there was a more personal basis . . . and I really enjoyed it.’

Walking Stick found there were benefits personally as well, because ‘there is a comfort level . . . If you needed extra time, he was there to talk to you more – even after the class was over.' He continued by saying,

> Maybe just going to the right teacher . . . could help a person out a lot because maybe you can talk more sociably . . . If you see that you are getting frustrated, . . . [you] can just take a break and … then go back to it after.

Walking Stick found that he could now find himself thinking about science all day and if he got a problem 'stuck in [his] head,' he would 'think about it until [he] figures it out.' Last, but not least of the remarks made by Walking Stick was that it certainly did not hurt to have someone behind you and motivating you and, for him, that was his teachers and his peers.

Bee

Bee, a returning student, began her high school career at this Midwestern school. Bee transferred to another school at the end of the previous school year and transferred back to the Midwestern school of the study. At the time of the interview, Bee had been in the Midwestern school for about a month.

Bee became a force to be reckoned with in the science classroom. She began the biology course at the Midwestern school at the beginning of the second quarter of the school year, and was actively involved in her new environment. Bee seemed to just be happy to be back at this school. She was a person with 'a new attitude at school.' While in her first semester back, she joined a school club, while working with one of the school's organizations and taking some of the pre-college courses. Bee told the interviewer that when she saw insects, she was scared of them, but did not know the reason why; for certain.

Bee began her story by saying, ‘I’m here to prove to myself that insects are not something that should be feared, but something to see differently.’ Because the focus in this study was on using insects and hands-on science together, Bee was in a perfect place. She went into details regarding how science had not been her best subject in school, because she did not see the need to understand it. Bee went on to say, ‘It’s never been a strong suit in my schooling.’ Bee continued and said, ‘In the science lab setting, it was mostly instructors guiding us through the lab, not students being able to figure this out on their own.’ She explained to the interviewer, ‘what she did in these classes was going deeper . . . I did not learn a lot when we would do the activities [in previous classes].’

Bee did the homework sheets in her previous science class that she said ‘were not learning, but just resaying.’ Bee said once the study concluded, ‘As far as my point of view, I think I had a lot of success with it [the study]. It’s just that when I got to actually do something [in the lab setting], I don’t know if I just froze up.’ Bee later said, ‘It helped me a lot, but I was afraid of it at first. The hands-on really helped me learn!’

Ant

Ant, a public high school student at the Midwestern school of the study, was in her first biology course. She said in the interview, ‘I am only working in this study to meet a boy.’ Per the researcher, this was an unintended consequence of the study parameters.

Ant decided that she wanted more out of school and knew that to get more out of school she had to be part of more. Ant has told the interviewer, ‘she is dedicated to school even though it is hard for her sometimes.' There was no question that Ant was devoted to her school, and to this study. When Ant was talking about herself at the beginning of the interview, it was evident that she focused on her goals and concerns about the school around her. There were many times during the interview that Ant had to be redirected to the question being asked, instead of a tangent that she wanted to go on. She admitted, it 'was kind of hard at first – being in a study that used insects.' Ant recalled, 'Looking over my science work and not really understanding it because it was not interesting was hard for me. I couldn't catch on no matter what I tried to do.' Ant felt that asking questions of her previous science teacher in class for help was not allowed. Ant said,

> The teacher just seemed to be there, never really wanting to help us out. It was hard to connect with her. But when I was able to work on the study that is when I found I . . . liked to do this different type of science.

Ant really became acquainted with her teacher during the study. It seemed as though she was even proud of her teacher and who she, herself, was as an individual. Ant said, 'I saw that my grade was going down and I was struggling and getting aggravated – I thought I better go to the teacher for help!' Ant went on to say,

> [The researcher] took his time, and he was nice and slow with it, and he made sure that everybody in there knew what they were doing before he moved on to another step or section in the study. That's what I liked about him; he took it step by step.

Ant recalled a time after a question and answer section during the study, 'and I was able to talk not only to the teacher but to my peers and they made sense, if not more than the teacher!' and I was so proud for once at my own learning.'

Ant said she wanted to learn with this hands-on style used during the study. Ant concluded the interview by describing her over all comparison of the hands-on learning and using the insects as something she may want to do again, but it may have to be some time before she touched another insect again.

Earwig

Earwig, was a student in the Midwestern school who was taking an honors biology class. This student possessed a strong stature and polished background from his family. He came to see the interviewer, asked for more information about the study after the informal meeting for volunteers, and Earwig asked if he could help with a deeper understanding of the study by participating.

Earwig began by asking before the interview truly began, 'What made [the Interviewer] go [to college] and what was [my] own drive?' As this was not part of the overall study, it did provide for the interviewer an interesting look into the thinking of Earwig. The interviewer began to work with Earwig saying [the researcher] wanted to find something that he could own. Earwig responded, 'that is what I want in the world is to be remembered.' He went on with saying, 'Even though school comes very easily for me, I always feel that there is so much more that I should be learning, but don't.'

As the interview progressed, Earwig made it well known that the hands-on learning style used in the study was what he loved to use in all of his classes. He continued to say, 'I just have to get my mind set to do it [hands-on activities] because I have to get through the material so that I can go further.' He said, 'I wish science was just putting everything together instead of how I have been taught before [handouts, movies, projects etc.], because I would feel that I too could have a better learning of it all.'

Wasp

Wasp, was a public high school student at the school of study, but informed the interviewer that she would be leaving at the end of the semester. Wasp was very difficult to 'get a hold of for the interview.' She indicated her willingness to participate right away in the study, but getting her to sit down for an interview took at least five weeks after the others interviewed. Wasp was obviously reluctant to talk and be recorded; Wasp said prior to and after the recording was completed some thought provoking things to the interviewer.

Wasp spoke about her lack of skill in science and said that she 'did not even have to do this type of science in the high school that she was at previously, before starting at the school of the study.' Now that she was in a biology class, she was appreciative of the learning that was happening, but she felt that she was never going to get ahead in the class. She was happy to have help because when she did not 'get it in class,' she knew that '[she]'d get it through talking to someone else.' She continued, 'And then if I didn't get it [understanding of the material] through her peers,' she said, 'I would feel as though I would the next time, with a pause [she hoped].'

She went into the positive aspect of doing the hands-on learning with the insects; according to Wasp, one was the availability of redoing the experiment at her own house. 'If we had a [lab], we could go back to repeating it at my own house… It was very helpful. I really enjoyed it!' She added that it was nice 'to have a place to go [during the study] and they'd explain stuff to you so you could go home and really think about it.' Wasp concluded the interview with, 'That was what I thought was the best out of this type of work. I could think on my own.'

Moth

Moth attended the Midwestern school of the study, and had taken a biology course before, in her high school career. Moth was as quiet as you could imagine. She would not raise her voice in anger or in conversation. She asked to be in the study and was very hesitant about being in the study, due to working with insects. She told the interviewer that when she found out that she would be learning with beetles, that she almost threw up.

Moth said, 'I probably would have not even gotten another chance at doing something like this because it was just not something that was done at school.' Hoping to ease Moth into interview mode, [the interviewer] asked her to say a little about what Moth learned in the study. She said, '[science is] something I always wanted to do better at school but was always too scared to feel like I would fail. I feel like a five-year old that questions everything, but no one has an answer or wants to answer.' As the conversation progressed to science, Moth told me,

> It probably was the first time that I actually felt like I was learning science. I felt I just needed that extra help. I like the backup more than just the class . . . because the [regular] teacher would just say what he had to say; he was not really explaining enough. I just needed more explaining, more help and more details . . . [because] there were a lot of things I didn't know . . . and he wasn't

going to take the time to do it. It was pretty much one-on-one . . . [the researcher] made me understand what I needed to learn.'

Cicada

Cicada was in repeat mode for this biology class where the study took place. Cicada told [the interviewer] that he happened to come into the study to see if it could help him finally pass this class. He was here because he said this was, 'my last ditch effort to learn science.'

Cicada was one of the few students who agreed to participate in the study who wanted to know the results of his completed work. He was always willing to try anything in the study, except when it came to touching the insect. Cicada said, 'I would do anything else for this study but, when the insects came out, I went weak in my knees.'

Cicada was very up front with everybody and perhaps this was his background. He continued by telling [the interviewer], 'I feel that science is now a part of me, I never knew that feeling before.'

Conclusion

The researcher collected and analyzed data on using entomological research as a tool for hands-on science in secondary education for high-poverty urban students. Throughout the study the experimental group, as well as a control group, were observed for the purpose of making sure that all individuals followed the same procedure for completing the study. A *z*-test conducted for the study's results, which confirmed the hypothesis that the use of hands-on entomological research increased students' understanding in the science classroom. The means and standard deviation for each research question showed significant change for participants between the beginning and end of the study. The experimental group of 30 volunteers went from negative to positive answers in response to questions related to entomological research in a school setting. Furthermore, results gleaned from a survey and questionnaire administered both before and after the experiment confirmed the pedagogical value of hands-on science as well as research-based learning. The researcher therefore concluded that the study's hypothesis was correct from his qualitative and quantitative data.

Chapter Five: Discussion, Conclusions, and Recommendations

In this study, the researcher looked at action research by secondary students in a high-poverty urban location. A review of the literature revealed three themes that came up repeatedly over the course of the study: hands-on learning, research, and urban settings. The guiding light in this research was how hands-on science in the classroom was affected by entomological research. The scholarly and empirical data confirmed the researcher's expectation.

The study concluded that entomological research increased scientific inquiry by urban students enrolled at Normandy High School in the Midwest. The study's results support the findings of previous studies by Turpin (1992), Freeman (1997), and Stohr-Hunt (1996). Learning science by the use of structured research and hands-on activities is more effective, the results show, than learning in a traditional manner (i.e., lecture).

The researcher conducted this study over a period of 25 days. Within that period, hands-on activities were completed 10 times in 25 class periods. Using so many hands-on activities with high-poverty urban students may have skewed the results. However, the study ratifies previous scholarship on the positive effects of hands-on instruction on secondary students' achievement and attitude toward science in general, though no earlier work was completed on entomological research in this context. The study thus provides educational leaders with another tool for support of the use of hands-on learning in science classes.

Purpose of the Study

The purpose of this research study was to investigate how using entomological research could be used to promote hands-on science inquiry. This investigative, action research study came about to consider using entomological research to promote hands-on science inquiry. This study utilized an on-line survey of secondary students from a high-poverty urban setting in the Midwest. Participants of the investigative study were directed to score the marked responses using a Likert scale for statements concerning how they felt about using insects in a science class. Participants were also requested to answer open-ended questions related to the survey statements and participate in an interview.

Hypotheses and Research Questions

H1a: Following participation in the hands-on entomological research science unit, students will not exhibit a difference in understanding of science concepts, measured by a comparison of pre-to-post Survey Questions (# 3, 5, 8, and 9).

H2a: Following participation in the hands-on entomological research science unit, students will not exhibit a difference in perceptions and attitudes concerning science, measured by a comparison of pre-to-post Survey Questions (# 1, 2, 3, 4, 6, 7), and 10.

RQ 1: How does hands-on science affect students' perspective on learning?

RQ 2: How does hands-on science affect students' understanding of concepts?

RQ 3: How can using research in a science class improve hands-on education?

RQ 4: How does using entomological research contribute to improving science education?

RQ 5: How can entomological research improve high-poverty students' learning science?

Variables

The independent variable in this investigative study was the entomological research to help with the hands-on science model.

The dependent variable in the study was how effective the hands-on model of learning was when implemented with entomological studies.

Methodology

This research study used both quantitative and qualitative means of data collection to provide a clear picture of the information collected. For the quantitative data, the researcher focused on the main points of the study, which were hands-on science inquiry and entomological research by urban students. The researcher developed an online pre and post-survey. The participants in the study were asked to rate responses to the 10 pre and post-survey questions, regarding their views on hands-on science inquiry, entomological research, and science within their school setting, which was an urban school setting in the Midwest. Each one of the statements in the pre and post-survey asked the students to rate their feelings regarding agreement and disagreement per the following scale: strongly disagree, disagree, neither agree nor disagree, agree, and strongly agree. After the students had completed the pre and post-survey during the different time frames of the study, there was a follow-up, open-ended questionnaire that the participants were to fill out to provide more detail of the information collected from the pre and post-survey. Between the pre and post-survey of the study, there was an interview process that provided a more personal one-on-one response, as well as, providing for more detail to an individual's thinking as the study was proceeding. At the conclusion of the study, there was a session with 10 of the 30 participants. This provided the researcher an open interaction from the participants on their viewpoints of the work and the participants' feelings regarding what they had learned during the study. The quantitative side of this research tested to see if there was a statistically significant difference in the number of students responding in the desirable range that established by the researcher. It decided for this study that in order to test the alternative hypothesis the alpha value for the *z*-test was set at 0.05, which provided a confidence level of 95%.

The next piece of the study that used for data collection was the questionnaire that also used as a pre and post-model data collection tool. The students that answered the questions from the open-ended questionnaire were then collected, analyzed for similar answers, and each one of those responses grouped accordingly to the coding that the researcher had established from the open-ended responses.

Quantitative Analysis

The quantitative data of this study derived from 10 pre and post-survey statements. Participants were able to select one of five possible responses: Strongly Agree, Somewhat Agree, Sometimes, Somewhat Disagree, and Strongly Disagree. The researcher considered Neither Disagree nor Agree, Agree, and Strongly Agree as desirable. The responses Strongly Disagree, Disagree, Neither Disagree nor Agree were considered undesirable by the researcher. It established that, if the percentage of any of the desirable responses fell within the critical area, the null hypothesis would be rejected and the alternative hypothesis supported. The survey questions were: 1) Do you like insects? 2) Do you enjoy science? 3) I feel that I learn better using hands-on options; 4) Science is harder for me than most of my classmates; 5) Have you ever used insects in a science class before? 6) Is science useful for solving practical problems in life? 7)

Scientific work is interesting; 8) All insects have eight legs? 9) Have you ever used research in your science class? and 10) Do you enjoy it when a science teacher lectures?

For nine of 10 pre survey statements, participants' responses were positive. Question 10 elicited negative responses. Answers to these questions indicated a measurable difference between perceptions of the hands-on learning model using entomological research and a traditional learning model involving lectures, when comparing pre-to-post responses to the survey. Therefore, the statistical results from questions one through nine, along with the increase in positive response percentage from pre-to-post, led the researcher to reject the null hypotheses and support the alternative hypotheses. The quantitative data thus supported the study's conclusion and the researcher's original view that entomological study could promote hands-on science learning in the high school classroom for high poverty students.

Implications

This action research study supported the educational thought that students' exposure to entomological research would not only support an increase in their scientific understanding, but also support appreciation of a new mode of learning. Science delivers a subtle impact on every facet of life for every individual (McComas et al., 2002). After reviewing the literature related to entomological research and scientific understanding, strategies were created to bring into the classroom more insect related science activities, for purposes of this study. The analysis of the data from the research supported the model of using insects to promote hands-on science in the classroom.

The creation of a positive connection between entomological research and student's exposure supported the growth of students in a high school setting to apply more of their own learning in a safe environment, such as the classroom. This allowed students to provide valuable information to the instructor during the class. Individuals with background knowledge in general science literacy help with promoting general understanding of the world around them (National Research Council, 1996). An understanding of science will aid in the creation of new ideas that will help influence student achievement in general science (Zhang, 2008). Science educator training on research revealed that most school-aged students retain information best by experiences taken from new knowledge (Golick et al., 2010).

The purpose of this research study was to find how hands-on science could promote by using entomological research in a high poverty, urban setting with students in a Midwest school district. The term hands-on science, explained by Ruby (2001), was to include, "all hands-on activities carried out by students during a science class" (p. 7). Hands-on science education has been rising in its usage from the 1970s (Ingison, 1978). Recent to this writing, hands-on science instruction came under fire. Writers were questioning if it was the correct method to teach science and if it supported the goals of science education (Ruby, 2001). The three reoccurring themes of this research, study of hands-on science inquiry, entomological research, and urban settings are located in the research literature in Chapter Two.

Limitations

This research study consisted of a small number of participants. The total of 30 students who participated was not representative of a random sampling of research subjects. Because the number of participants was relatively small and the study setting was limited to one secondary school, it may be difficult to replicate the findings.

Originally, 227 students approached to participate in the study. That number represented 95% of the population of the biology students at Normandy High School. Out of this population, only 30 agreed to participate in the study. This small segment decreased the overall strength of the research study and its findings. A related limitation was that, in the interest of ensuring privacy rights, no demographic data were collected on student participants' backgrounds, including such factors as their school, and families' income levels.

The students included in the study were all from a high-poverty urban setting in a Midwest secondary school. Because all the participants were minors, letters were required indicating parental permission and a student willingness (assent) letter to participate in the action research study. Collecting data in the form of a survey and of a questionnaire also created a limitation, due to the issues of students' responses versus their ability to comprehend what the questions were specifically asking. Another limitation of this research study was that the researcher had to limit his contact with the participants because of his role as a teacher in the urban school setting, to remove all potential bias and coercion from the study procedures.

Recommendations for Further Research

There are many different recommendations that this researcher would like to see this experiment take in regards to further research. The researcher's first recommendation is to increase the number of participating subjects in the experiment. A larger pool of high-poverty urban students would provide more opportunities to correlate the data and presumably substantiate its findings. This would also allow for a higher possibility of a random sampling to take place, with more subjects in the pool.

The second recommendation is any research conducted during future experiments would also benefit from gathering more background data about the participants. This study was conducted at the high school level. In future research, it would be useful to know, for example, whether the students introduced to insects were in an elementary, middle, or junior high setting.

The third recommendation for further research is to take this experiment into a middle school setting and replicate the experiment. This would allow researchers to make a connection to how the students responded at a middle school setting and see if it correlates to the high school setting.

The fourth recommendation is that for a researcher who might conduct this experiment again not be an entomologist. I believe that, due to the researcher's experience as an entomologist, there could have been a possible bias that might have limited in the experiment. The researcher furthermore recommends that, if this experiment is repeated again in another location, an entomologist be a part of the team to help analyze the lesson, but not be involved in presenting the lesson.

The last recommendation would be to perform this research experiment within a similar population of high poverty students, but from a different region, besides the Midwest. This would allow for students and researchers conducting the experiment to show if there is a possible connection of experiences in urban settings in different locations.

All of the recommendations I believe would provide for a better experiment that would provide different results than those collected by is researcher for this study. Any change would allow new experiments to create and allow students exposure to a better hands-on science experience.

Conclusion

This mixed-methods study examined how teaching practices in an urban secondary school improved by incorporating entomological research and hands-on science. The researcher collected and analyzed data on using entomological research as a tool for hands-on science in secondary education for high-poverty urban students. Throughout the study the experimental group, as well as a control group, were observed for making sure that all individuals followed the same procedure for completing the study. A *z*-test conducted for the study's results, which confirmed the hypothesis that the use of hands-on entomological research increased students' understanding in the science classroom. The means and standard deviations for Likert-scale responses to each research question showed significant change for participants between the beginning and end of the study. The experimental group of 30 volunteers increased the percentage of positive response to questions related to entomological research and hands-on science in a school setting. Furthermore, results gleaned from a survey and questionnaire administered both before and after the experiment, along with responses to interview questions, confirmed the pedagogical value of hands-on science, as well as research-based learning. The researcher, therefore, concluded that the study's hypotheses were supported. Through their exposure to entomological research, participants were able not only to increase their scientific understanding, but also to appreciate a new model of learning. The strength of this study is indebted to the work completed by other researchers before this project.

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Appendices

A. Approval Letter from School

B. Letter of Research

C. Lindenwood University Informed Consent for Parents to Sign for Student Participation in Survey Research Activities

D. Lindenwood University Informed Consent for Parents to Sign for Student Participation in Interview Research Activities

E. Lindenwood University Adolescent (Ages 13-17) Assent to Participate in Survey Research

F. Lindenwood University Adolescent (Ages 13-17) Assent to Participate in Interview Research

G. Transcript of Questionnaire and Interview Data

Appendix A: Approval Letter from School

Date: 07/15/2015
Dr. Derrick Mitchell
Normandy High School Principal
6701 St. Charles Rock Road, Saint Louis, MO 63133

Permission to Conduct Research Study

Dear Dr. Mitchell:

I am writing to request permission to conduct a research study at Normandy High School. I am currently enrolled in the Doctoral Program at Lindenwood University in Saint Charles, MO, I am in the process of writing my dissertation. The study is entitled, "An action research project using entomological research to promote hands-on science inquiry, in a high poverty, urban setting with secondary students."

I hope that the school administration will allow me to recruit up to 40 individual students who are a mixture of males and females from the schools Biology classes to anonymously complete a 2-page pre and post questionnaire (copy enclosed), and a pre and post survey. Interested students, who volunteer to participate, will be given a consent form to be signed by their parent or guardian (copy enclosed) and returned to the primary researcher at the beginning of the survey process.

If approval is granted, student participants will complete the survey in a classroom or other quiet setting on the school site. This will be completed after school in Central Room 268 as long as permission is granted for this research. The survey process should take no longer than 30 minutes to complete. The survey results will be pooled for the dissertation and individual results of this study will remain absolutely confidential and anonymous. Should this study be published, only pooled results will be documented. No costs will be incurred by either your school/center or the individual participants.

Your approval to conduct this study will be greatly appreciated. I will follow up with a telephone call next week and would be happy to answer any questions or concerns that you may have at that time. You may contact me at my email address: dustin.stockmann@hotmail.com.

If you agree, kindly sign below and return the signed form in the enclosed self-addressed envelope. Alternatively, kindly submit a signed letter of permission on your institution's letterhead acknowledging your consent and permission for me to conduct this survey/study at your institution.

Sincerely,

Dustin Stockmann and Lindenwood University

Enclosures

Approved by:

Derrick Mitchell [signature] 7/27/15

Print your name and title here Signature Date

Appendix B: Letter of Research

Hello. My name is Mr. Dustin Stockmann. I am a graduate student at Lindenwood University in its doctoral program. I am conducting research on using the study of entomological (insects) research to promote hands-on science learning, and I am inviting you to participate because you are students who are studying science in a biology classroom.

Before I explain the research project, I want it to be known that participation in this study is optional, though your participation in the regularly scheduled activities of the science course in which you are enrolled is not. If you or your parents feel that you do not wish to participate, that is alright. You have the option to decline at the start of the study, and you can quit the study at any time if you so wish.

Participation in this research includes taking two surveys about your attitudes toward using entomological research and hands-on science, which will take approximately 15 minutes per survey. If you agree to participate in an interview about your views, a person other than your regular science teacher or I will ask the questions. The interview will take approximately 10 to 20 minutes. If you agree to participate in a focus group, that will take approximately 30 to 45 minutes. Your total time commitment for all these activities will be between 70 and 95 minutes.

If you have any questions or would like to participate in the research, I can be reached at 314-493-0600 or Ds204@lionmail.lindenwood.edu. For this research project my university advisor is Dr. John Long, who can be reached at 636-949-4937.

Appendix C: Lindenwood University Informed Consent for Parents to Sign for Student Participation in Survey Research Activities

INFORMED CONSENT FOR PARENTS TO SIGN FOR STUDENT PARTICIPATION IN SURVEY RESEARCH ACTIVITIES

An Action Research Project Using Entomological Research
to Promote Hands-On Science Inquiry

Principal Investigator: Dustin Stockmann
Telephone: 636-208-4648 E-mail: ds204@lindenwood.edu

Participant: ____

Parent Contact Information: __________________________________

Dear parent,

1. Your child is invited to participate in a research study conducted by Dustin Stockmann under the guidance of Dr. John Long The purpose of this research is to examine to what extent entomological research (insects) can promote hands-on learning of students in a high poverty, urban secondary setting. This project will examine the potential benefits, perceptions, shortcomings, and results of using entomological research in the area of hands-on science learning.

2. a) Your child is expected to participate in regularly required classroom activities. However, your child's participation, specifically in the research study activities, will involve

- The procedure that your child will be completing this study, if they choose to, is by first completing a pre survey regarding their understanding of using insects and research in the classroom. 10 to 15 days following the end of the regular classroom study unit, a post survey will be given to the students who are participating that will measure how effective they feel the model of hands-on science inquiry worked for the students.
- .

Approximately [30-50 students] may be involved in this survey research.

b) The amount of time involved in your child's participation will be in this research includes taking a two surveys about your attitudes toward using entomological research (insects) and hands on science, which will take approximately 15 minutes per each survey. If your child participates in the survey, the interview, and the focus group, the total time commitment will be between 70 – 95 minutes.

3. There may be certain risks or discomforts to your child associated with this research. They include the close proximity to insects, such as beetles, ants, or crickets. What I will do to help minimize the risks is ask the student if they would want to handle the different insects. The student will always be the one to tell me of their discomforts. If

the student does not want to participate during the times in which insects will be used, they will have the option to opt out from that part of the experiment.

4. There are no direct benefits for your child's participation in this study. However, your child's participation will contribute to the knowledge about using entomological research to promote hands-on science and may help society

5. Your child's participation is voluntary and you may choose not to let your child participate in this research study or to withdraw your consent for your child's participation at any time. Your child may choose not to answer any questions that he or she does not want to answer. You and your child will NOT be penalized in any way should you choose not to let your child participate or to withdraw your child.

6. We will do everything we can to protect your child's privacy. As part of this effort, your child's identity will not be revealed in any publication or presentation that may result from this study. In some studies using small sample sizes, there may be risk of identification.

7. If you have any questions or concerns regarding this study, or if any problems arise, you may call the Investigator, Dustin Stockmann at 314-493-0600) or the Supervising Faculty, Dr. John Long at 636-949-4937). You may also ask questions of or state concerns regarding your participation to the Lindenwood Institutional Review Board (IRB) through contacting Dr. Marilyn Abbott, Provost at mabbott@lindenwood.edu or 636-949-4912.

I have read this consent form and have been given the opportunity to ask questions. I will also be given a copy of this consent form for my records. I consent to my child's participation in the research described above.

___________________________	___________________________
Parent's/Guardian's Signature Date	Parent's/Guardian's Printed Name
___________________________	
Child's Printed Name	
___________________________	___________________________
Signature of Investigator Date	Investigator Printed Name

Revised 8-8-2012

Appendix D: Lindenwood University Informed Consent for Parents to Sign for Student Participation in Interview Research Activities

INFORMED CONSENT FOR PARENTS TO SIGN FOR STUDENT PARTICIPATION IN INTERVIEW RESEARCH ACTIVITIES

An Action Research Project Using Entomological Research
to Promote Hands-On Science Inquiry

Principal Investigator: Dustin Stockmann
Telephone: 636-208-4648 E-mail: ds204@lindenwood.edu

Participant: ____

Parent Contact Information: ___________________________________

Dear parent,

1. Your child is invited to participate in a research study conducted by Dustin Stockmann under the guidance of Dr. John Long The purpose of this research is to examine to what extent entomological research (insects) can promote hands-on learning of students in a high poverty, urban secondary setting. This project will examine the potential benefits, perceptions, shortcomings, and results of using entomological research in the area of hands-on science learning.

2. a) Your child is expected to participate in regularly required classroom activities. However, your child's participation, specifically in the research study activities, will involve

- The procedure that your child will be completing this study, if they choose to, is by first completing a pre survey regarding their understanding of using insects and research in the classroom. 10 to 15 days following the end of the regular classroom study unit, a post survey will be given to the students who are participating that will measure how effective they feel the model of hands-on science inquiry worked for the students.
- .

Approximately [30-50 students] may be involved in this survey research.

b) The amount of time involved in your child's participation will be in this research includes taking a two surveys about your attitudes toward using entomological research (insects) and hands on science, which will take approximately 15 minutes per each survey. If your child participates in the survey, the interview, and the focus group, the total time commitment will be between 70 – 95 minutes.

3. There may be certain risks or discomforts to your child associated with this research. They include the close proximity to insects, such as beetles, ants, or crickets. What I

will do to help minimize the risks is ask the student if they would want to handle the different insects. The student will always be the one to tell me of their discomforts. If the student does not want to participate during the times in which insects will be used, they will have the option to opt out from that part of the experiment.

4. There are no direct benefits for your child’s participation in this study. However, your child’s participation will contribute to the knowledge about using entomological research to promote hands-on science and may help society

5. Your child’s participation is voluntary and you may choose not to let your child participate in this research study or to withdraw your consent for your child’s participation at any time. Your child may choose not to answer any questions that he or she does not want to answer. You and your child will NOT be penalized in any way should you choose not to let your child participate or to withdraw your child.

6. We will do everything we can to protect your child’s privacy. As part of this effort, your child’s identity will not be revealed in any publication or presentation that may result from this study. In some studies using small sample sizes, there may be risk of identification.

7. If you have any questions or concerns regarding this study, or if any problems arise, you may call the Investigator, Dustin Stockmann at 314-493-0600) or the Supervising Faculty, Dr. John Long at 636-949-4937). You may also ask questions of or state concerns regarding your participation to the Lindenwood Institutional Review Board (IRB) through contacting Dr. Marilyn Abbott, Provost, at mabbott@lindenwood.edu or 636-949-4912.

I have read this consent form and have been given the opportunity to ask questions. I will also be given a copy of this consent form for my records. I consent to my child’s participation in the research described above.

____
Parent’s/Guardian’s Signature
Date

____
Parent’s/Guardian’s Printed Name

____
Child’s Printed Name

____
Signature of Investigator
Date

____
Investigator Printed Name

Revised 8-8-2012

Appendix E: Lindenwood University Adolescent (Ages 13-17) Assent to Participate in Survey Research

Lindenwood University

ADOLESCENT (Ages 13-17) ASSENT TO PARTICIPATE IN SURVEY RESEARCH

An Action Research Project Using Entomological Research
to Promote Hands-On Science Inquiry

You are asked to participate in a research study conducted by Mr. Dustin Stockmann, a student at Lindenwood University. You were selected as a possible participant in this study because you are a student in the Normandy Schools Collaborative at Normandy High School in a Biology class. Your participation in this research study is voluntary.

Why is this study being done?

I am conducting research on using entomological research (insects) to promote hands-on science inquiry (learning), and I am inviting you to participate because you are students who are studying science in a biology classroom.

What will happen if I take part in this research study?

Please talk this over with your parents before you decide whether or not to participate. We will also ask your parents to give their permission for you to take part in this study. But even if your parents say "yes" you can still decide not to do this.

If you volunteer to participate in this study, the researcher will ask you to do the following:

Participation in this research includes taking a two surveys about your attitudes toward using entomological research (insects) and hands on science, which will take approximately 15 minutes per each survey. Someone other than your teacher will hand out and collect the surveys. If you participate in the survey, the interview, and the focus group, your total time commitment will be between 70 – 95 minutes.

Are there any potential risks or discomforts that I can expect from this study?

There are certain risks or discomforts associated with this research. They include the close proximity to insects such as beetles, ants, or crickets. What I will do to help minimize the risks is ask you if you would want to handle the different insects. You will always be the one to tell me of your discomforts. If you do not want to participate during the times in which insects will be used, you will have the option to opt out from that part of the experiment.

Are there any potential benefits if I participate?

You will not directly benefit from your participation in the research.

The results of the research may contribute to the knowledge about using entomological research to promote hands-on science

Will I receive any payment if I participate in this study?

You will receive no payment for your participation.

Will information about me and my participation be kept confidential?

Any information that is obtained in connection with this study and that identify you will remain confidential. It will be disclosed only with your permission or as required by law.
Confidentiality will be maintained by means of the use of study codes on data documents. This information will be kept at the principal researcher's residence in a locked cabinet. The coding of information from participants will be on a matrix that only the principal investigator will have access to.

What are my rights if I take part in this study?

You may withdraw your assent at any time and discontinue participation without penalty or loss of benefits to which you were otherwise entitled.

You can choose whether or not you want to be in this study. If you volunteer to be in this study, you may leave the study at any time without consequences of any kind. You are not waiving any of your legal rights if you choose to be in this research study. You may refuse to answer any questions that you do not want to answer and still remain in the study.

Who can answer questions I might have about this study?

If you have any questions, comments or concerns about the research, you can talk to the one of the researchers. Please contact Dustin Stockmann at 314-493-0600 or the Supervising Faculty, Dr. John Long at 636-949-4937.

If you wish to ask questions about your rights as a research participant or if you wish to voice any problems or concerns you may have about the study to someone other than the researchers, please contact Office of the Provost at mabbott@lindenwood.edu.

SIGNATURE OF STUDY PARTICIPANT

I understand the procedures described above. My questions have been answered to my satisfaction, and I agree to participate in this study. I have been given a copy of this form.

Name of Participant

Signature of Participant

Date

SIGNATURE OF PERSON OBTAINING ASSENT

In my judgment the participant is voluntarily and knowingly agreeing to participate in this research study.

Name of Person Obtaining Assent

Contact Number

Signature of Person Obtaining Assent

Date

Appendix F: Lindenwood University Adolescent (Ages 13-17) Assent to Participate in Interview Research

Lindenwood University

ADOLESCENT (Ages 13-17) ASSENT TO PARTICIPATE IN INTERVIEW RESEARCH

An Action Research Project Using Entomological Research to Promote Hands-On Science Inquiry

You are asked to participate in a research study conducted by Mr. Dustin Stockmann, a student at Lindenwood University. You were selected as a possible participant in this study because you are a student in the Normandy Schools Collaborative at Normandy High School in a Biology class. Your participation in this research study is voluntary.

Why is this study being done?

I am conducting research on using entomological research (insects) to promote hands-on science inquiry (learning), and I am inviting you to participate because you are students who are studying science in a biology classroom.

What will happen if I take part in this research study?

Please talk this over with your parents before you decide whether or not to participate. We will also ask your parents to give their permission for you to take part in this study. But even if your parents say "yes" you can still decide not to do this.

If you to participate in an interview -it regular biology If you participate in the survey, the interview, and the focus group, your total time commitment will be between 70 – 95 minutes.

Are there any potential risks or discomforts that I can expect from this study?

There are certain risks or discomforts associated with this research. They include the close proximity to insects such as beetles, ants, or crickets. What I will do to help minimize the risks is ask you if you would want to handle the different insects. You will always be the one to tell me of your discomforts. If you do not want to participate during the times in which insects will be used, you will have the option to opt out from that part of the experiment.

Are there any potential benefits if I participate?

You will not directly benefit from your participation in the research.

The results of the research may contribute to the knowledge about using entomological research to promote hands-on science

Will I receive any payment if I participate in this study?

You will receive no payment for your participation.

Will information about me and my participation be kept confidential?

Any information that is obtained in connection with this study and that identify you will remain confidential. It will be disclosed only with your permission or as required by law.
Confidentiality will be maintained by means of the use of study codes on data documents. This information will be kept at the principal researcher's residence in a locked cabinet. The coding of information from participants will be on a matrix that only the principal investigator will have access to.

What are my rights if I take part in this study?

You may withdraw your assent at any time and discontinue participation without penalty or loss of benefits to which you were otherwise entitled.

You can choose whether or not you want to be in this study. If you volunteer to be in this study, you may leave the study at any time without consequences of any kind. You are not waiving any of your legal rights if you choose to be in this research study. You may refuse to answer any questions that you do not want to answer and still remain in the study.

Who can answer questions I might have about this study?

If you have any questions, comments or concerns about the research, you can talk to the one of the researchers. Please contact Dustin Stockmann at 314-493-0600 or the Supervising Faculty, Dr. John Long at 636-949-4937.

If you wish to ask questions about your rights as a research participant or if you wish to voice any problems or concerns you may have about the study to someone other than the researchers, please contact Office of the Provost at mabbott@lindenwood.edu.

SIGNATURE OF STUDY PARTICIPANT

I understand the procedures described above. My questions have been answered to my satisfaction, and I agree to participate in this study. I have been given a copy of this form.

____
Name of Participant

____________________________________ _____________________
Signature of Participant Date

SIGNATURE OF PERSON OBTAINING ASSENT

In my judgment the participant is voluntarily and knowingly agreeing to participate in this research study.

____________________________________ _____________________
Name of Person Obtaining Assent Contact Number

____________________________________ _____________________
Signature of Person Obtaining Assent Date

Appendix G: Transcript of Questionnaire and Interviews

Pre-Questionnaire

Research Question 1: How does hands-on science affect a student's perspective on learning?

Code	**Statement or Interview Transcript**	
B 1.1	Evidence of Growth	
	Student 1:	I can't identify a bug by its shape.
	Student 2:	I know that a bug has eight legs.
	Student 6:	I know that bugs are that scarry (*sic*).

Code	**Statement or Interview Transcript**	
B 1.2	Evidence of Expectations	
	Student 22:	I do not know any thing (*sic*) about bugs.
	Student 26:	Well, it can be if I know the bug is because if I don't know what the bug do, then I'm not touching it.
	Student 27:	I don't wanna (*sic*) know bout (*sic*) no bugs.

Code	**Statement or Interview Transcript**	
B 1.3	Evidence of Self-Perception	
	Student 3:	I am enthusiasm (*sic*) towards insects.
	Student 15:	No, because some stuff is really hard to me.
	Student 17:	Level 1
	Student 19, 21, 28:	IDK (*sic*)
	Students 4, 5, 10, 16, 20, and 30:	I do not know.

Code	**Statement or Interview Transcript**	
B 1.4	Evidence of Life-Enhancement	
	Student 7:	If I am smart, tehn (*sic*) I can learn.
	Student 18:	If I am hungry, then I must eat.

Code	**Statement or Interview Transcript**	
B 1.5	Evidence of Support	
	Student 12:	Me having fun in class
	Student 29:	Us learning in the classroom

Research Question 2: How does hands-on science affect student understanding of concepts?

Code	**Statement or Interview Transcript**	
B 2.1	Evidence of Growth	
	Student 8	All of the students collected information from out of the book.
	Student 29:	Hands-on stuff

Code	**Statement or Interview Transcript**	
B 2.2	Evidence of Expectations	

Code	Statement or Interview Transcript	
	Student 18:	No, because some stuff is really hard to me.
	Student 25:	I don’t care.
Code	**Statement or Interview Transcript**	
B 2.3	Evidence of Self-Perception	
	Student 9:	I like leanrinf (*sic*) about science.
	Student 12:	My hypothesis is “my” guess from what I see.
Code	**Statement or Interview Transcript**	
B 2.4	Evidence of Life-Enhancement	
	Students 11, 13, 14, 23, 24:	Huh
	Students 1, 2, 3, 4, 5, 6, 7, 8, 9, 15, 17, 18, 19, 27, 28, 29, 30:	I don’t know.
Code	**Statement or Interview Transcript**	
B 2.5	Evidence of Support	
	Students 10, 17, 23:	Hands on helps me learn.
	Student 27:	I lke (*sic*) it when the teacher lectures.
Research Question 3: How does using research in science class help improve science education for students?		
Code	**Statement or Interview Transcript**	
B 3.1	Evidence of Growth	
	Students 11, 13, 14, 22, 24:	Huh
	Students 1, 2, 3, 4, 5, 6, 7, 8, 9, 15, 16, 18, 19, 27, 28, 29, 30:	I don’t know.
Code	**Statement or Interview Transcript**	
B 3.2	Evidence of Expectations	
	Student 12:	Research helps me learn from smarter people.
	Student 25:	Research doesn’t help anyone.
Code	**Statement or Interview Transcript**	
B 3.3	Evidence of Self-Perception	
	Student 20:	Research helps me feel important and that I am learning.
	Student 26:	Science is fly if you (k)now why.
Code	**Statement or Interview Transcript**	
B 3.4	Evidence of Life-Enhancement	
	Student 21:	If there was no research, then I wouldn’t know anything.
	Student 30:	Science gave me my phine [phone].
Code	**Statement or Interview Transcript**	
B 3.5	Evidence of Support	
	Student 15:	Science is everywhere.
	Student 27:	Science is dependable.

Research Question 4: How does using entomological research help improve science education?

Code	Statement or Interview Transcript	
B 4.1	Evidence of Growth	
	Students 1-30	I do not know.

Code	Statement or Interview Transcript	
B 4.2	Evidence of Expectations	
	Student 7:	Bugs are grose (*sic*).
	Student 18:	Insects are cool.
	Student 24:	Can we cut one open?

Code	Statement or Interview Transcript	
B 4.3	Evidence of Self-Perception	
	Student 9:	I don't want a bug by me.
	Student 19:	What can bugs do for us?

Code	Statement or Interview Transcript	
B 4.4	Evidence of Life-Enhancement	
	Student 19:	What can bugs do for us?
	Student 25:	Bugs I know are used for makeup.

Code	Statement or Interview Transcript	
B 4.5	Evidence of Support	
	Student 5:	Whay (*sic*) should I learn about bugs?
	Student 12:	What can bugs teach us?

Research Question 5: How does entomological research improve high-poverty students' learning of science?

Code	Statement or Interview Transcript	
B 5.1	Evidence of Growth	
	Student 3:	Bugs are everywhere.
	Rest of Students:	I don't know.

Code	Statement or Interview Transcript	
B 5.2	Evidence of Expectations	
	Student 16:	Research means work. I don't like work.
	Student 30:	Bugs can help me in science cuz [because] they are everywhere.

Code	Statement or Interview Transcript	
B 5.3	Evidence of Self-Perception	
	Student 7:	You could get questions answered if you classify them on a question. . . . Sometimes you don't have questions based on what you want to know and you could guess on what the artifacts are used for.
	Student 15:	Context is the stuff around stuff.

Code	Statement or Interview Transcript

B 5.4	Evidence of Life-Enhancement	
	Student 9:	Umm, I put down the stuff where you take something out of where it belongs. iI ruins the what you are learning.
Code	**Statement or Interview Transcript**	
B 5.5	Evidence of Support	
	Student 21:	Because you don't know if they [bugs] are really peaceful because it doesn't say that they are peaceful or there isn't any information that they are peaceful.

Post-Questionnaire
Research Question 1: How does hands-on science affect a student's perspective on learning?

Code	**Statement or Interview Transcript**	
C 1.1	Evidence of Growth	
	Student 1:	I can identify a bug by its shape.
	Student 2:	I know that a bug has six legs.
	Student 6:	I know that bugs aren't that really scarry (*sic*).
Code	**Statement or Interview Transcript**	
C 1.2	Evidence of Expectations	
	Student 22:	I feel that I understand science inquiry much better. It means to me that if I have a question, then I can ask it.
	Student 26:	Ask a question, do background research, construct a hypothesis, analyze data, and draw conclusions from your results.
	Student 27:	Scientific inquiry from my understanding is when the real world activities are related to science. What it means to me is that many insects from the outside world can be used for different science experiments.
Code	**Statement or Interview Transcript**	
C 1.3	Evidence of Self-Perception	
	Student 3:	My current understanding in science inquiry is ok, but I feel like I can do better. These are the steps for science inquiry thw whole scientific method
	Student 15:	I know that insects can be found any and everywhere. Some of them

		communicate by . . .
	Student 17:	Level 2
	Students 19, 21, 28:	I feel bugs are okay with me.
	Students 4, 5, 10, 16, 20, and 30:	I do not like bugs.

Code	Statement or Interview Transcript	
C 1.4	Evidence of Life-Enhancement	
	Student 7:	Insects have antennae. So do phones. So that’s communication.
	Student 18:	It is ok, exciting, and fun. Insects can be found everywhere you go through a transitional stage called puberty.

Code	Statement or Interview Transcript	
C 1.5	Evidence of Support	
	Student 12:	Learning everything because there is so much
	Student 29:	The only challenging part for me is trying to do something fun (such as the activity) but learn and retain at the same time.

Research Question 2: How does hands-on science affect student understanding of concepts

Code	Statement or Interview Transcript	
C 2.1	Evidence of Growth	
	Student 8	Paying attention and staying focused on the object
	Student 29:	The most challenging aspect might be the listening and getting all the information.

Code	Statement or Interview Transcript	
C 2.2	Evidence of Expectations	
	Student 18:	To actually follow the safety rules because anything can happen.
	Student 25:	Their [there] is no challenge if you are following the instructions of the science teacher.

Code	Statement or Interview Transcript	
C 2.3	Evidence of Self-Perception	
	Student 9:	I learned that the connections are the most important part of science.
	Student 12:	I think I will learn . . . and get a new understanding.

Code	Statement or Interview Transcript	
C 2.4	Evidence of Life-Enhancement	
	Students 11, 13:	I learned that an insect’s natural

		habitat is like our own.
	Students 1, 2, 3, 4, 5, 6, 7, 8, 9, 15, 17, 18, 19, 27, 28, 29, 30:	Insects are like us, they need something to get them going . . . stimulus, sugar, caffeine.
Code	**Statement or Interview Transcript**	
C 2.5	Evidence of Support	
	Students 10, 17, 23:	Hands-on science gives me an ability to learn what they [insects] do.
	Student 27:	I like it when the teacher lectures. [Answer did not change from previous time asked.]
Research Question 3: How does using research in science class help improve science education for students?		
Code	**Statement or Interview Transcript**	
C 3.1	Evidence of Growth	
	Students 22, 24:	Research helped my group understand the insect better.
	Students 1, 2, 6, 9, 15, 16, 30:	Science is questions, research is help to the questions.
Code	**Statement or Interview Transcript**	
C 3.2	Evidence of Expectations	
	Student 12:	Research gave me an answer on why do insects more move on this paper than others.
	Student 25:	Research does help a lot of people.
Code	**Statement or Interview Transcript**	
C 3.3	Evidence of Self-Perception	
	Student 20:	Research helps me feel important and that I am learning.
	Student 26:	Science is fly if you (k)now why.
Code	**Statement or Interview Transcript**	
C 3.4	Evidence of Life-Enhancement	
	Student 21:	Basically, I looked at where pieces were on insects . . . could make an estimate on how they did things in nature.
	Student 30:	Science said if there is something outside then they [insects] probably worked outside.
Code	**Statement or Interview Transcript**	
C 3.5	Evidence of Support	
	Student 15:	The race made me learn about how does surfaces matter.
	Student 27:	It’s really fun and easy sometimes now since I have been doing more.
Research Question 4: How does using entomological research help improve science		

education?

Code	Statement or Interview Transcript	
C 4.1	Evidence of Growth	
	Students 7,12, 16, 24:	The bug research we did showed me that science is important.

Code	Statement or Interview Transcript	
C 4.2	Evidence of Expectations	
	Student 7:	Bugs are neat.
	Student 18:	Insects are different.
	Student 24:	What happens to them when they die?

Code	Statement or Interview Transcript	
C 4.3	Evidence of Self-Perception	
	Student 9:	I don't want a bug by me, but I can tolerate it.
	Student 19:	Bugs do a lot for us!

Code	Statement or Interview Transcript	
C 4.4	Evidence of Life-Enhancement	
	Student 19:	What can bugs do for us?
	Student 25:	Yeah, because when I thought about science I just thought they were just using stuff in a class, not outside too.

Code	Statement or Interview Transcript	
C 4.5	Evidence of Support	
	Student 5:	Whay (*sic*) should I learn about bugs?
	Student 12:	What can bugs teach us?

Research Question 5: How does entomological research improve high poverty students learning of science?

Code	Statement or Interview Transcript	
C 5.1	Evidence of Growth	
	Student 3:	Bugs are everywhere, and that is a good thing.

Code	Statement or Interview Transcript	
C 5.2	Evidence of Expectations	
	Student 16:	You can use science at the same time to study one thing and. . . . Um, like, uh, the bugs we used science. . . . But it's hard to explain.
	Student 30:	Science doesn't study the insects in school. They should. It's cool!

Code	Statement or Interview Transcript	
C 5.3	Evidence of Self-Perception	
	Student 7:	Science is different when you use insects because you get to have more

		fun.
	Student 15:	I think science is studying about organisms, ecosystems, about earth and stuff.

Code	**Statement or Interview Transcript**	
C 5.4	Evidence of Life-Enhancement	
	Student 9:	You study global warming, animals, and bugs.

Code	**Statement or Interview Transcript**	
C 5.5	Evidence of Support	
	Student 21:	Bugs rule the world. I see this now. What can I learn from them things.

Vita

Dustin Ray Stockmann graduated from the De Soto R-73 School District in 2005. After receiving an Associate of Arts certificate from Jefferson College, he earned a Bachelor of Arts degree in Elementary Education in 2010 and a Master of Science degree in Curriculum and Instruction in 2012, both conferred by Missouri Baptist University. He, then, was awarded a certificate in Advanced Science Education by Washington University. He has also received a Master of Science degree in School Administration and an Educational Specialist certificate in Educational Leadership from Lindenwood University, as well as a Master of Science degree in Entomology from the University of Nebraska- Lincoln in Entomology. Now in his seventh year as a teacher, he anticipates completing his Educational Doctorate in Pre-K through 12 Educational Leadership in 2016.