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A MIXED-METHODS STUDY OF ENTOMOLOGY INCORPORATION IN U.S. SECONDARY SCIENCE INSTRUCTION

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by

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To encourage understanding and appreciation of insects, entomology education advocates have supported and encouraged K-12 teachers to integrate insects and insect-related content into formal science instruction. However, research examining how and why science teachers incorporate entomology into secondary science courses is limited.

A sequential explanatory mixed-methods research study was conducted to address this gap. The study was conducted in two phases. During the first phase, quantitative survey research was conducted with a representative sample of 254 U.S. secondary life science teachers. During the subsequent qualitative phase, follow-up interviews were conducted with a purposeful sample of 18 survey participants and an opportunistic sample of three secondary science teachers with experience incorporating entomology content in their science instruction. Data were analyzed separately, and quantitative and qualitative findings integrated to form a more complete understanding of how and why teachers' incorporate entomology content in U.S. secondary science instruction.

Results from this study (1) characterize entomology incorporation practices in a representative sample of U.S. secondary science classrooms, (2) identify factors that facilitate or hinder secondary science teachers' entomology incorporation efforts, and (3) elicit teacher perspectives on how K-12 entomology education resources or supports can be designed to meet teacher needs.

Findings indicate that a diverse assortment of insects are commonly incorporated into classrooms, but that incorporation generally occurs less than once per month. Lesson plans and live insects are commonly used to support incorporation of entomology content. Factors that impact teachers' entomology incorporation efforts include teachers' attitudes and beliefs, prior entomology experiences, as well as external variables such as amount of instructional time available and fit with approved curriculum or state or national science standards. These insights are especially valuable as they come directly from in-service life science teachers who are in the best position to identify obstacles and provide their feedback on preferred resources to address identified barriers. Recommendations for entomology and science education organizations include development of appropriate resources to address potential gaps in curriculum and professional development offerings.

DEDICATION

This dissertation is dedicated to my family whose love and encouragement has seen me through. To my mom, Mary Ingram, your unwavering support is a force of nature. I am forever grateful to have you in my corner. To my dad, Mike Ingram, for modeling hard work and fostering my appreciation of the outdoors. To my brother, Eric, for being unapologetically yourself and showing me the value of finding your own path. To my sister, Emily, for being my best friend and partner in crime over the years and across the miles.

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CHAPTER 1: INTRODUCTION

With an estimated one million described species, insects represent over half of Earth's biodiversity (The World Conservation Union, 2014) and outnumber humans 200 million to one (G. B. Johnson, 2018). This staggering diversity and abundance has led some to describe arthropods as the most dominant group of animals on Earth (Triplehorn, Johnson, & Borror, 2005). In their roles as pollinators, decomposers, predators, prey, disease vectors, agricultural pests, and important model organisms, insects impact human life in both positive and negative ways.

Despite inextricable connections between humans and insects, research has demonstrated that insects are often overlooked, oversimplified, or misunderstood (Kellert, 1993; Leandro & Jay-Robert, 2019; Shipley & Bixler, 2017; Snaddon & Turner, 2007; Snaddon, Turner, & Foster, 2008). Evolutionarily, humans may have benefited from increased fear and aversion to insects and other arthropods by avoiding painful and potentially venomous bites or stings (Lockwood, 2013). However, as reports of declining insect biodiversity emerge (Hallmann et al., 2017), the public's lack of awareness or understanding of insects' value could have dire consequences for ecosystem functioning and food security (Basset & Lamarre, 2019). It has been argued that if members of the public are to make informed decisions about emerging societal issues related to entomology, they will need to broadly understand entomology and to acknowledge the value and necessity of insects (Pearson, Skinner, & Hoback, 2007).

To become entomologically literate, the public will need opportunities to experience entomology in an educational setting where assumptions and misconceptions can be addressed. Formal science classrooms led by trained education professionals may offer a venue for such learning experiences. Various approaches have been documented to integrate entomology into science instruction such as field-based research experiences (Golick, Schlesselman, Ellis, & Brooks, 2003; Lamarre, Juin, Lapied, Gall, & Nakamura, 2018; Richardson & Hari, 2008), classroom-based experiments or investigations (Heyborne, Fast, & Goodding, 2012; Miller & Naples, 2002; Richardson & Hari, 2009; Shaffer, Warner, & Hoback, 2007; Van Hoeck, 2010; Wagler & Moseley, 2005), and online simulations (B. T. White, 2012).

Not only does formal education offer a potential avenue for increased entomological literacy, but insects provide many potential benefits when used as teaching tools in the K-12 science classroom (Matthews, Flage, & Matthews, 1997). Research has shown that incorporation of insects into science instruction can support inquiry-based teaching practices (Boardman, Zembal-Saul, Frazier, Appel, & Weiss, 1999; Golick, Heng-Moss, & Ellis, 2010), positive student learning outcomes (Killermann, 1998; Lamarre et al., 2018; Sammet & Dreesmann, 2017), and increased student motivation (Sammet, Kutta, & Dreesmann, 2015). When used as concrete examples of abstract science concepts or as cost-effective, accessible model organisms in scientific experiments and investigations, live insects offer tangible connections to life outside the science classroom and the opportunity to engage in authentic science experiences (Matthews et al., 1997).

K-12 entomology education literature has largely focused on students' conceptions and perceptions of insects and other arthropods (Barrow, 2002; Leandro & Jay-Robert, 2019; Prokop, Prokop, & Tunnicliffe, 2008; Prokop, Usak, Erdogan, Fancovicova, & Bahar, 2011; Prokop & Tunnicliffe, 2008; Shepardson, 1997, 2002;

Snaddon & Turner, 2007; Snaddon et al., 2008). Limited research has focused on K-12 teachers and factors that might impact the likelihood of teachers incorporating insects into future science instruction, and this literature has predominantly focused on pre-service (Wagler & Wagler, 2011, 2012) and in-service elementary teachers (Golick et al., 2010). Therefore, a gap in the literature exists in describing in-service secondary science teachers' incorporation practices, motivations, and perceptions during selection and implementation of entomological content in their science classrooms. Research is needed to systematically explore the process of entomology incorporation as it currently stands. The findings of this study will provide the field of entomology with insights into teachers' curricular choices and guidance on how to serve the evolving needs of U.S. secondary science educators. In addition, findings from this study seek to highlight how insects and other arthropods might be leveraged as effective teaching tools in the era of Next Generation science education reform efforts.

While much anecdotal evidence and limited research findings have supported the supposition that insects and other arthropods are presented in science classrooms and used as classic examples and model organisms, the question remains: How and why do U.S. secondary science teachers incorporate entomology education within the broader context of science instruction and how can those committed to entomology education in the K-12 arena more effectively support this incorporation?

Purpose Statement

The purpose of this explanatory sequential mixed methods study was to characterize the state of entomology education in a representative sample of U.S. secondary science classrooms and examine teacher-centered perspectives related to entomology incorporation practices in secondary science classrooms. This study aimed to develop a more complete understanding of how and why secondary teachers incorporate insects into their science instruction, so that the field of entomology can develop strategies to support high-quality entomology education in formal classroom settings at the secondary level.

The study was conducted in two phases. The first phase of the study was the development and implementation of a quantitative web-based survey of secondary science teachers to characterize the process of entomology incorporation in a formal science education setting. The aim of the survey was to quantitatively characterize how insects are being incorporated in a representative sample of U.S. secondary science teachers and to recruit survey respondents to participate in the qualitative phase of the study. In the second phase of the study, a basic qualitative approach (Merriam, 2009) was taken in which rich, qualitative data were collected on teachers' entomology incorporation practices and perceptions. Semi-structured follow-up interviews were conducted with a purposeful sample of 18 survey respondents from across the U.S. Additionally, three Nebraska secondary science teachers with diverse entomology incorporation experiences were recruited through opportunistic sampling and data were collected via in-depth interviews, classroom observations, and instructional artifacts. The aim of the basic qualitative approach was to collect rich, detailed accounts of teachers' entomology incorporation experiences that could be analyzed to elaborate, confirm, or explain findings from the quantitative strand. By combining quantitative and qualitative methods, the goal of this study was to more fully articulate the process of entomology incorporation from various teacher perspectives and strengthen confidence in the survey results by triangulating findings from the two strands.

Audiences Who Will Benefit

This dissertation will be of interest to diverse audiences. The study findings will be broadly applicable to the field of science education and will be of particular interest to professionals interested in K-12 entomology education. The emphasis of this study is on producing a more complete understanding of the instructional needs and practices of in-service secondary science teachers as they enact entomology education content in their classrooms.

Research Questions

This mixed methods study focused on three key research questions. The researcher determined that the strengths and weaknesses of quantitative and qualitative methods could be offset by bringing these fundamentally different approaches to bear on each key research question. For each key question, quantitative sub-questions were first explored and then coupled with an explanatory qualitative sub-question.

RQ1: How can entomology incorporation be characterized in U.S. secondary science instruction?

1. Quantitative: To what extent (i.e. frequency, diversity of insect types presented, and number of entomology topics, science concepts, and science practices supported) is entomology incorporated in secondary science instruction?
2. Quantitative: What percentage of teachers use curriculum materials or supports (i.e. lesson plans or live insects) when incorporating entomology in secondary science instruction?

3. Quantitative: What are the most important barriers preventing teachers from incorporating entomology in secondary science instruction?
4. Qualitative: What perceived outcomes do secondary science teachers associate with incorporating entomology into their science instruction?

RQ2: Why do teachers choose to incorporate entomology into secondary science instruction?

1. Quantitative: How can secondary science teachers' entomology incorporation attitudes and beliefs related to entomology incorporation be characterized?
2. Quantitative: What percentage of teachers have had formal or informal entomology experiences prior to incorporating entomology into secondary science instruction?
3. Quantitative: Which factors (use of curriculum materials and supports, teachers' prior entomology experience, or teachers' attitudes) are associated with different levels of teachers' entomological incorporation in secondary science instruction?
4. Qualitative: How do the realities of formal science classrooms facilitate or limit secondary science teachers' entomology incorporation practices?

RQ3: How can the entomology community help support high quality entomology incorporation in U.S. secondary science instruction?

1. Quantitative: Which curriculum materials, training, or supports would teachers prefer when planning for future entomology incorporation in their science instruction?
2. Qualitative: How do curriculum materials (i.e. lesson plans) meet the needs of teachers incorporating entomology in their secondary science instruction?

Significance of the Study

This study aims to contribute to the growing body of entomology education literature. The findings from this study provide a more complete understanding of secondary science teachers' entomology incorporation practices and perspectives. Insights gleaned from this study are intended to inform pragmatic entomology education efforts to serve the science education needs of secondary teachers both in the U.S. and abroad. The discussion provides specific recommendations for entomology education professionals regarding the development of curriculum and professional development workshops to broaden and strengthen future K-12 entomology education.

Definition of Terms

Entomology incorporation: The presentation of or interaction with any media depicting an insect such as a picture, video, audio, text, lecture, discussion, activity, lesson, pinned specimen, live insect, etc.

In-service teacher: A teacher who is fully employed and no longer part of a teacher training program.

Pre-service teacher: A person who is enrolled in a teacher training program and is not yet fully employed.

Characterization: The description of the features of something. In this study, features of entomology incorporation being characterized include frequency of incorporation, diversity of insect types incorporated, number of entomology topics, science concepts, and science practices supported via incorporation, curricular supports used, and presentation of live insects

Affect: A broad variety of noncognitive constructs including emotion, attitude, belief, motivation, self-concept, etc.

Attitude: Psychological tendency made up of cognitive, affective, and motivational facets and expressed by evaluating a particular entity positively or negatively.

Belief: The cognitive facet of attitude; an estimation of the likelihood that the knowledge one has about an entity is correct or, alternatively, that an event or a state of affairs has or will occur.

Motivation: The process whereby goal-directed activities are energized, directed, and sustained.

Emotion: Multifaceted, short-lived episodes that are evoked by a variety of stimuli and involve coordinated psychological processes including affective, cognitive, physiological, motivational, and expressive components.

Curriculum materials: resources designed to be used by teachers in classrooms to guide their instruction

Philosophical Foundations

Post-positivism is the commonly accepted worldview that governs research in the field of entomology. This research paradigm is characterized by the shared belief that the role of a researcher is to be impartial when collecting data and using deductive reasoning to accept or reject hypotheses to understand a single reality (Creswell & Plano Clark, 2011). While this philosophical foundation may fit the purpose and needs of entomology research, the assumptions and beliefs that underpin the post-positivist worldview did not entirely meet the needs of this study situated in the social sciences (Onwuegbuzie & Leech, 2005). Pragmatism may offer what post-positivism cannot- a middle ground allowing for both the existence of a singular reality that can be characterized and the acknowledgement that multiple perspectives of this reality exist (Creswell & Plano Clark, 2011). A hallmark of pragmatism is a needs-based, pluralistic approach in which procedures from both quantitative and qualitative approaches are selected and combined to meet the needs and research objectives of the study and findings are used to address real-world issues (R. B. Johnson & Onwuegbuzie, 2004).

A pragmatist worldview has shaped decisions throughout the study in the following ways:

- A sequential explanatory mixed methods design was selected to meet the need for a generalizable understanding of incorporation practices from a representative sample of U.S. teachers while simultaneously identifying and recruiting participants for the follow-up qualitative strand.
- Survey research and basic qualitative research methods were selected for their feasibility within both time and financial constraints while addressing the research purpose.
- When collecting and analyzing quantitative data, a deductive approach was used and descriptive and inferential statistics were calculated to provide a generalizable snapshot of teachers' entomology incorporation practices.
- When collecting and analyzing qualitative data, an inductive approach was used in which themes emerged from the data and diverse teacher perspectives were presented using rich, thick description.

- Quantitative results and qualitative findings were compared and combined during interpretation to provide a more complete understanding of entomology incorporation than either method could provide on its own.
- Findings from the study informed pragmatic, real-world recommendations related to curriculum development and professional development training intended to be enacted in applied education settings.

Delimitations and Limitations

The study is delimited by its focus on U.S. secondary life science teachers and may not represent the experiences or perceptions of teachers from other countries due to differences in science education policies, culture, and context. In addition, this study focuses on teachers' entomology education experiences within the scope of high school grade levels (grades 9-12) and does not include teachers from middle school grades (grades 6-8). While teachers from a diverse cross-section of life science courses (e.g. general biology, AP biology, environmental science, horticulture, etc.) were recruited, the scope of this study does not include the presentation of entomology within the physical sciences (physics, chemistry, geology, etc.).

Several important limitations informed research design choices for this study. Due to time and financial constraints, this study is limited to a providing a snapshot of entomology incorporation rather than a longitudinal study tracking teachers' experiences over time. The lack of availability of survey instruments focused on entomology education in K-12 classrooms and limited ability to identify and gain access to a population of in-service secondary teachers with experience incorporating entomology into their science instruction made creation and implementation of a survey instrument an appropriate approach within the study in order to 1) identify participants with the necessary entomology education experiences and 2) recruit participants for the qualitative phase of the study. Lastly, this study is largely descriptive and exploratory (as opposed to explanatory) in nature due to the limited information available in the research literature on teachers’ entomology education experiences especially at the secondary grade level.

CHAPTER 2: LITERATURE REVIEW

This literature review is designed to explore questions relevant to understanding the process of entomology incorporation in K-12 science classrooms. What is the goal of K-12 science education in the U.S.? What is the role of entomology in supporting science literacy? What factors influence teachers' entomology incorporation practices? What efforts have been made to support teachers in teaching with or about insects in the formal science classroom? What is the need for this study?

What is the goal of K-12 science education in the U.S?

Over the past 35 years, calls for changes in the U.S. education system and the development of innovative science curriculum has brought about national interest in science education reform. During the late 1980's, the U.S. established national education goals and developed standards to guide curriculum, instruction, and assessment (National Research Council, 1996). Throughout this era, seminal science education reform documents have stated that science literacy is the central goal of effective K-12 science education (American Association for the Advancement of Science, 1989; National Research Council, 1996, 2012, 2013).

Science literacy is broadly defined as "the ability to use scientific knowledge to make informed personal and societal decisions" (Lederman, 2003). Since the late 1950's, educators, researchers, and advocates have redefined the term (Laugksch, 2000), and while no single definition has achieved universal acceptance, various interpretations have more commonalities than differences and the term succeeds in conveying a complex idea in simplistic terms (Bybee, 1997; Holbrook & Rannikmae, 2007). The working definition for science literacy used for this study comes from *A Framework for K-12 Science*

Education (from here on denoted as the *Framework)* which guided development of the most recent national science education standards known as the Next Generation Science Standards (NGSS):

> "By the end of the 12th grade, students should have gained sufficient knowledge of the practices, crosscutting concepts, and core ideas of science and engineering to engage in public discussions on science-related issues, to be critical consumers of scientific information related to their everyday lives, and to continue to learn about science throughout their lives." (National Research Council, 2012, p. 9)

Since the mid-1990's, science education reform documents including Science for All Americans from Project 2061 (American Association for the Advancement of Science, 1989) and the National Science Education Standards (National Research Council, 1996) have outlined necessary learning outcomes to promote a scientifically literate society. Current reform efforts embodied by the NGSS call for students to engage in science and engineering practices in order to construct an understanding of core science ideas and cross-cutting concepts that are shared across the various science fields (NGSS Lead States, 2013). As of September 2019, 44 states and the District of Colombia (representing 71% of U.S. students) have officially adopted the NGSS or similar *Framework*-based standards ("NGSS Hub," n.d.). Based on the prominent role the *Framework* and NGSS play in directing science education at the present time, these science education reform documents will be used to frame the study presented here.

What is the role of entomology in supporting science literacy?

The literature suggests that entomology can serve science education's overarching science literacy goal in two key respects. First, entomology is an important discipline within the branch of biological science and represents a body of science content worthy of study, in and of itself, in a typical K-12 life science course. Secondly, insects have long been touted as valuable teaching tools in K-12 science classrooms when used as concrete examples of abstract science concepts or as model organisms suitable for classroom investigations or controlled experiments. To put it more simply, the literature suggests that science literacy can be supported by teaching *about* insects and teaching *with* insects.

Teaching about insects

Distinguished biologist and entomologist, E.O. Wilson (1987) highlighted the influence of invertebrates calling them “the little things that run the world”. With nearly one million described insect species successfully inhabiting nearly every type of habitat over the past 350 million years, insects impact humans in a variety of ways every day (Triplehorn et al., 2005). Benefits include insect pollination of many agricultural crops and wild plants, nutrient cycling by scavengers and decomposers, biological control of economically important pest insects and plants by natural enemies, and scientific research and medical advances achieved with the aid of insects as model organisms. Insects also serve as an important food source for birds, fish, and other animals; produce a number of commercial products including silk, honey, and beeswax; and are considered by many to be unusual and intriguing creatures worthy of study (Triplehorn et al., 2005). Conversely, a small portion of insects have proven to be devastating pests of agricultural crops and stored products, and others can transmit diseases impacting the health of humans and other animals (Triplehorn et al., 2005).

Insects clearly play an integral role in our daily life and it has been argued that as a subset of scientific literacy, citizens should have a basic understanding of insects (Fischang, 1976; Pearson et al., 2007). In addition, Creager (1976) points out that besides the issue of human impact, “there are so many species of insects that any course intended to give an overview of biology would be incomplete without some consideration of insects.”

Pearson and colleagues (2007) proposed an initial framework of basic competencies of an entomologically literate population based on findings from a 64-question survey of 234 practicing entomologists. Survey results suggested the importance of students being able to understand and explain the value of insects to humans. From this core competency, five entomological literacy elements were identified, and detailed supporting concepts were developed. Their findings suggest that the general public should be able to 1) explain how insects provide environmental services to humans, 2) develop the ability to use insects in inquiries and provide examples of insects’ investigative value, 3) understand and provide examples of insects’ economic value, 4) understand that insects should not be controlled without considering risks and benefits, and 5) appreciate that insects have aesthetic value.

Relatively few studies have examined entomology education in K-12 classrooms, however, in these cases, researchers have tended to focus on characterizing what students in primary grades understand *about* insects (rather than focusing on understanding of broad science content taught *with* insects). Findings from these studies indicate that student understanding of insects is limited and lacking dimension even in primary grade levels (Barrow, 2002; Shepardson, 1997, 2002).

Shepardson (1997) conducted a study of 24 first-grade students' understanding of the life cycle of butterflies and beetles through four life stages: egg, larva, pupa, and adult. Using pre- and post-interviews and analysis of student journals and small-group discussion, Shepardson (1997) remarked that previous informal experiences are valuable in constructing meaning of new concepts. Pre-assessment journal entries indicated students lacking previous physical experience with butterflies or beetles could not accurately explain their development (i.e. students did not incorporate all life stages into their model). During instruction, students observed the development of beetles and butterflies from life stages egg through adult. Observation of the life cycle of butterflies and beetles paired with teacher discourse and small-group discussions aided students in developing an accurate, four-stage model of complete metamorphosis. However, gaps in student knowledge persisted. Some students continued to struggle to differentiate between the larval and pupal stages. Others linked complete metamorphosis to all types of insects including those that experience gradual, incomplete, or no metamorphosis. This is not surprising, as different insect life cycles were not presented in classroom instruction. Journal entries showed that some students viewed pupae as dead possibly due to lack of locomotion during this life stage. Lastly, all students lacked a conceptual framework to understand the importance of metamorphosis as it aids in reducing competition for the same habitat and food sources between the different insect life stages. Again, this may not be a deficit in student understanding, but a deficiency in the presentation of insect life cycles as this concept was not explicitly taught during instruction.

Shepardson (2002) carried out an additional study with 120 students from grades kindergarten through fifth-grade (20 students per grade level) to investigate their ideas about insects and how these ideas changed over time. Data were collected via student drawings and explanations, semi-structured interviews, and student responses to the question, “What makes an organism an insect?” As data were analyzed, emergent core ideas and concepts were grouped into descriptive themes and triangulation was used to establish credibility of the researcher’s interpretation of the data. While more than 50% of students drew insects, many erroneously identified arthropod characteristics (antennae, segmented body, jointed legs) as exclusive to insects. Only at the fifth-grade level, could students accurately distinguish arthropods (such as spiders) from insects. Students generally viewed human-insect interactions as negative with primary grade level students (K-2) focusing on direct harm (e.g. bites or stings) compared to intermediate grade level students (3-4) focusing on indirect harm (e.g. plant damage). Beneficial aspects of insects were not noted during student interviews. In addition, students did not associate insect structure with function (i.e. flying connected to wings, hopping connected to legs). Primary-grade-level students defined organisms as insects based on size and shape (small and “bug-like”) whereas older students incorporated insect-specific characteristics (six legs, 3 body segments, and exoskeleton). Based on the results of this study, Shepardson (2002) recommended five steps for improved curricular design and instructional strategies involving insects. (1) Instruction should include opportunities for students to compare insects and non-insects in order to differentiate insect-specific characteristics. Exposure to larger specimens might help students to eliminate small size as a defining insect trait. (2) Students should explore insects in their natural habitat when possible to illustrate ecosystem interactions and services such as pollination and predator-prey relationships. (3) Students should examine different types of insect metamorphosis in order to better understand insect growth and development. (4) Survival mechanisms such as insect mimicry, offensive protection including biting or stinging, unpalatable taste, and camouflage should be presented to add dimension to students' ideas of insects as harmful creatures. (5) Instruction on social insects (honey bees, ants, termites) can be included to illustrate the diversity and complexity of insects as a group.

Barrow (2002) also investigated students' understanding of insect characteristics, life cycles, environments, and impacts on humans via interviews with fifty-six students in grades K-6. Student understanding of all aspects of entomological knowledge was considered limited and often erroneous. Students lacked an understanding of insect diversity and tended to base their responses on one or two familiar insects. Despite students' lack of entomological understanding, Barrow (2002) noted that students posed questions about insects during interviews indicating curiosity and interest about these animals.

Teaching with insects

Professionally-trained entomologists and researchers appear to see the innate value of teaching about insects in the K-12 classroom. However, entomology is not explicitly addressed in NGSS or previous national science education standards (National Research Council, 1996; NGSS Lead States, 2013) suggesting that there is no impetus for teachers to teach *about* insects in an effort to meet state-mandated education directives. In addition, research has reported a decline in representation of insects and natural history, more generally, in biology textbooks over time (Gangwani & Landin, 2018). If learning *about* insects is not required and insect presentation is declining in typical instructional supports such as textbooks, it is possible that entomology content is not being presented in K-12 science classrooms to support entomology literacy, but rather, to support broader science education goals.

As educators seek ways to meet science standards in the classroom and to illustrate the relevance and value of science in daily life, they may turn to insects and their associated systems as teaching tools in science education. The case has been made that insects can be used in science classrooms of all age and skill levels to teach basic life science concepts (Creager, 1976; Matthews et al., 1997). Matthews and colleagues (1997) suggest that the use of insects and other arthropods in formal science education is growing in popularity for a number of reasons. First, an abundance of insects are widely available for purchase or collection and are well suited for teaching a variety of scientific concepts. Next, increased restrictions on teaching and research with vertebrate animals have forced educators to consider alternatives including insects with fewer regulations. Finally, arthropods are a practical choice for classroom and laboratory study because of their dramatic changes in appearance, relatively short life cycles, low cost, and ease of handling.

Science education reform efforts have sought to shift teachers' instructional practice from a teacher-centered, didactic approach of lecturing about science content to a more student-centered, inquiry-based approach in which students engage in science practices to gain an understanding of core science ideas and concepts (National Research Council, 1996, 2012; NGSS Lead States, 2013). Therefore, in addition to using insects to teach about broader science ideas or connect classroom learning to the outside world, education researchers have explored the value of using insects as a tool to engage teachers in inquiry-based approaches in the science classroom (Golick & Heng-Moss, 2013; Golick et al., 2010, 2003; Leigh A. Haefner, Friedrichsen, & Zembal-Saul, 2006; Leigh Ann Haefner & Zembal-Saul, 2004). In this way, insects may be incorporated into science classrooms not as a means of teaching entomology content, but as a vehicle for engaging students in affordable, accessible, and authentic science practices that have relevance to their lived experiences.

What factors influence K-12 teachers' entomology incorporation practices?

Despite the value that insects bring to the formal science classroom as necessary content or effective teaching tools, teachers may or may not elect to present entomology content in their secondary science courses. Several studies have directly explored factors impacting teachers' entomology-related curriculum and instructional decisions. These studies focused on pre-service rather than in-service teacher experiences and explored the role that attitudes and beliefs play in influencing teachers' future entomology incorporation decisions (Wagler, 2010; Wagler & Wagler, 2011, 2012, 2013).

First, Wagler (2010) found a strong association between pre-service elementary teachers' attitudes and beliefs about insects and reported likelihood of incorporating insects into future instruction. This study provided a foundation for Wagler to explore factors impacting teachers' attitudes and beliefs about insects. Wagler and Wagler (2011) explored the impact that direct contact with a living insect during pre-service teacher training had on teachers' attitudes and beliefs toward insects. Findings showed that direct contact with Madagascar Hissing Cockroaches (MHC) increased teachers' reported likelihood of future MHC incorporation and improved attitudes toward MHC, but not to other insect species. These findings indicate that positive impact on teachers' attitudes and beliefs following direct contact with living insects may be limited to those insect species presented.

Interestingly, in Wagler and Wagler's continued examination of teachers' attitudes and beliefs and their impact on reported future incorporation decisions, results seemed to suggest that increased knowledge of insect biology does not necessarily lead to pre-service elementary teachers' adopting more positive attitudes and beliefs or increasing the likelihood of incorporating insects into future classroom instruction. Due to the extreme physical changes that many insects go through during their life cycle, Wagler and Wager (2012) explored the potential impact that exposing teachers to insects' different life stages might have on their attitudes and beliefs toward insects. Findings indicated that exposing pre-service elementary teachers to diverse insect morphology of insect species which are generally perceived positively (e.g. lady beetle, dragonfly, and butterfly) decreased pre-service elementary teachers' likelihood of incorporating these insects into future instruction. Lastly, Wagler and Wagler (2013) examined the impact that knowledge of arthropods' feeding habits (carnivory vs. herbivory) has on pre-service elementary teachers attitudes and beliefs and reported likelihood of future incorporation. Findings demonstrated that when teachers learned that an arthropod they believed to be an herbivore was actually a carnivore, attitudes and beliefs as well as the likelihood of future incorporation were negatively impacted. In contrast, when teachers learned that an arthropod that they believed to be a carnivore was actually an herbivore, attitudes and beliefs and likelihood of future incorporation were positively impacted.

Beyond the demonstrated importance of teachers' attitudes and beliefs, additional factors may influence teachers' decisions to include or exclude entomology from the science classroom. However, research on teacher decision-making provides limited guidance as researchers have struggled to create a meaningful framework that outlines how teachers' decision making leads to improved student outcomes (Borko, Roberts, & Shavelson, 2008). Instead, research has shifted to exploring ways to support teachers' professional development and skill building with the aim of influencing teacher practice (Borko et al., 2008). Current literature suggests that science teacher learning "is shaped not only by formal professional development opportunities but also by the demands of particular teaching contexts, the materials and human resources available to them, educational reform efforts, and policy mandates from their schools and states" (National Academies of Sciences, Engineering, and Medicine, 2016).

What efforts have been made to support teachers in teaching with or about insects in the formal science classroom?

To prepare and persuade teachers to present entomology during science instruction, entomology and science education advocates have enacted a variety of efforts to support teachers' entomology incorporation practices. Avenues to support teachers have included K-12 curriculum development and instructional supports such as insect care guides, professional development including pre-service and in-service teacher training and workshops, and entomology education mini-grants to support classroom study.

Curriculum materials such as lesson or unit plans and instructional supports such as insect care guides provide guidance to teachers seeking to present entomology content in their classrooms. A Google search conducted on 20 October 2019 using the search terms ‘entomology lesson plans’ yielded 554,000 results including a litany of curriculum materials from various sources including university-based entomology departments, zoos, museums, government agencies, and non-profit and for-profit organizations. Published lesson plans can be found in peer-reviewed practitioner journals to aid in teaching about experimental design (Golick, Ellis, & Beecham, 2006; Schwagmeyer & Strickler, 2011), growth and development (Ashbrook, 2007b; Hobbie, 2000), evolution and adaptation, (Constible & Lee, 2006; Gates, 2005; Terry, 2005), structure and function (Damonte, 2005; H. White, 2009), behavior (Bowen, 2008; Eason & LaManna, 2000; Newell, 1994; Travis, 2003), and ecology (Ashbrook, 2007a; Biggs, Miller, & Hall, 2006; Gates, 2002; Halverson & Lankford, 2009; Hevel, 2005; Huss & Baker, 2010). While numerous entomology-related curriculum materials are available, it is unknown if teachers are familiar with available materials, if available resources are readily accessible, if available resources are of high quality, or if existing resources meet teachers’ needs. Recent efforts are underway to collect and evaluate K-12 entomology education resources from many different sources for easy access in a single digital repository (“Welcome | Lesson Hive,” n.d.).

Identifying and selecting appropriate content to match course objectives is only one of many considerations with which teachers are concerned. If live insects are to be used in the classroom, teachers will need necessary guidance on how to safely, ethically, and successfully care for insects. To meet this need, entomology educators have published insect care guides to aid teachers in selecting appropriate insect model species, designing suitable classroom habitat, and establishing self-sustaining insect populations

(Alexander, 2012; Wagler, 2017). In addition, teachers must consider modifying instruction and materials accordingly to meet the needs of diverse learners. In such cases, entomologists have provided recommendations for adapting entomology education materials for students of differing abilities (Radavich, 2019).

Access to curriculum and instructional supports may not provide teachers with the content knowledge or teaching strategies necessary to successfully integrate new entomology content into the science classroom. To address this need, many university-affiliated entomology departments offer college-level entomology courses suitable for non-entomology majors or teacher training workshops involving insects specifically targeting educators. Such entomology education experiences can help teachers gain the necessary entomology and/or pedagogical content knowledge to successfully integrate insects in science instruction. Research has shown that inquiry-based, entomology-focused professional development offered via a face-to-face workshop (Golick et al., 2010), face-to-face course (Leigh A. Haefner et al., 2006), or online course (Golick & Heng-Moss, 2013) can provide teachers with necessary content knowledge and pedagogical knowledge about inquiry-based instructional approaches to feel confident in teaching about or with insects in the classroom.

Lastly, in an era of shrinking school budgets, lack of funding may present a barrier for teachers wishing to present entomology education in the K-12 classroom. To overcome this hurdle, the Chrysalis Fund, managed by the Entomological Society of America’s Education and Outreach Committee, provides a source of grant funding to support insect-themed programs or projects in the K-12 space.

What is the need for this study?

To better understand how entomology content can serve the overarching goal of science literacy in U.S. science education, it is important to explore how entomology education currently exists in K-12 science classrooms and why teachers are choosing to include or exclude insects from their science instruction.

A review of the literature suggests that while several studies and anecdotal evidence support the claim that insects and other invertebrates 1) should be presented in typical K-12 science classrooms and 2) can be used as effective teaching tools in K-12 classrooms, very limited data are available to characterize the prevalence or purpose for which teachers are electing to incorporate entomology education in U.S. science classrooms. In addition, existing literature provides insight into the important role that pre-service elementary teachers' attitudes and beliefs play in their future entomology incorporation practices, however, it is unclear if these findings can be generalized to in-service or secondary science teachers. Based on previous efforts to support entomology education in K-12 classrooms, it is possible that access to entomology curriculum materials, teachers' prior entomology education experiences, and external constraints such as limited funding may also impact teachers' entomology incorporation practices. Lastly, while a wealth of entomology curriculum materials would appear to be available for use in K-12 science classrooms and professional development experiences would appear to equip teachers to knowledgeably and confidently teach about or with insects, teacher-centered perspectives are needed to better understand and meet teachers' needs.

If entomology is to be incorporated broadly in K-12 science classrooms, we need a better understanding of how and why teachers select and implement materials into their instruction. Currently, the process of how and why insects are used in U.S. secondary science classrooms has not been systematically explored. This study seeks to address the gap in the literature by 1) describing the prevalence and nature of insect incorporation in secondary life science instruction 2) identifying factors that support or deter the incorporation of insects into science instruction; and 3) understanding how the science education and entomology communities can support teachers in their entomology education efforts.

This study provides a foundation for determining the state of entomological education in secondary grade levels and how insects are being used to support entomology literacy and broader science understanding. Findings from this study will provide insight into content and instructional practices of in-service (currently employed) secondary science teachers and can be used to develop appropriate resources to address potential gaps in curriculum offerings and student understanding while working within an evolving culture of science education.

CHAPTER 3: METHODS

Overview of Mixed Methods Research Approach

This study uses a mixed methods approach to explore how and why U.S. secondary science teachers incorporate entomological content into their classrooms. The use of mixed methods was established in the 1980s and has become widely accepted across disciplines including social, behavioral, and health sciences (Plano Clark & Ivankova, 2015). Plano Clark and Ivankova (2015) describe mixed methods research as the following:

> "A process of research in which researchers integrate quantitative and qualitative methods of data collection and analysis to best understand a research purpose. The way this process unfolds in a given study is shaped by mixed methods research content considerations and researchers' personal, interpersonal, and social contexts."

Rationale

In designing this study, two prominent rationales for using mixed methods were selected- offsetting strengths and weaknesses and complementarity (Plano Clark & Ivankova, 2015). In mixing both quantitative and qualitative methods, Plano Clark and Ivankova (2015) argue that more rigorous conclusions can be reached by combining the two approaches in ways that maximize their strengths while minimizing the limitations or weaknesses of single methods. In addition, different aspects of a single phenomenon can be examined using both quantitative and qualitative methods, allowing for more complete conclusions to be drawn.

Overall Research Design

A sequential Quan → Qual research design (Figure 3.1) was selected in which a quantitative phase was enacted followed by a qualitative phase (Plano Clark & Ivankova, 2015, p. 122). During the quantitative phase, a survey was designed and implemented to gather data on general trends in entomology incorporation within a representative U.S. secondary teacher sample and to identify participants who demonstrated varying levels of entomology incorporation for inclusion in the follow-up qualitative strand. During the qualitative strand, a basic qualitative approach was used to explore teacher-centered perspectives about how and why entomology was incorporated into their secondary science classrooms and ways this process could be improved or supported.

This research design was selected for three reasons. First, identifying an appropriately large sample of secondary teachers who present entomology content in their science instruction was a logistical challenge. Distributing the quantitative survey first to a sufficiently large sample of secondary science teachers allowed for identification of a representative sub-sample of teachers whose entomology incorporation practices, beliefs, and attitudes could be characterized, and a purposeful sample of potential follow-up participants could be identified and recruited for inclusion in the qualitative strand. Second, the selection of a design with sequential rather than concurrent timing was determined to be easier to implement by the primary investigator (Ingram) with limited time and financial resources. Third, the sequential timing of the two phases allowed the primary investigator to focus on findings of interest from the quantitative survey and gather follow-up qualitative data to elaborate, explain, or confirm initial quantitative results (Plano Clark & Ivankova, 2015, p. 122).

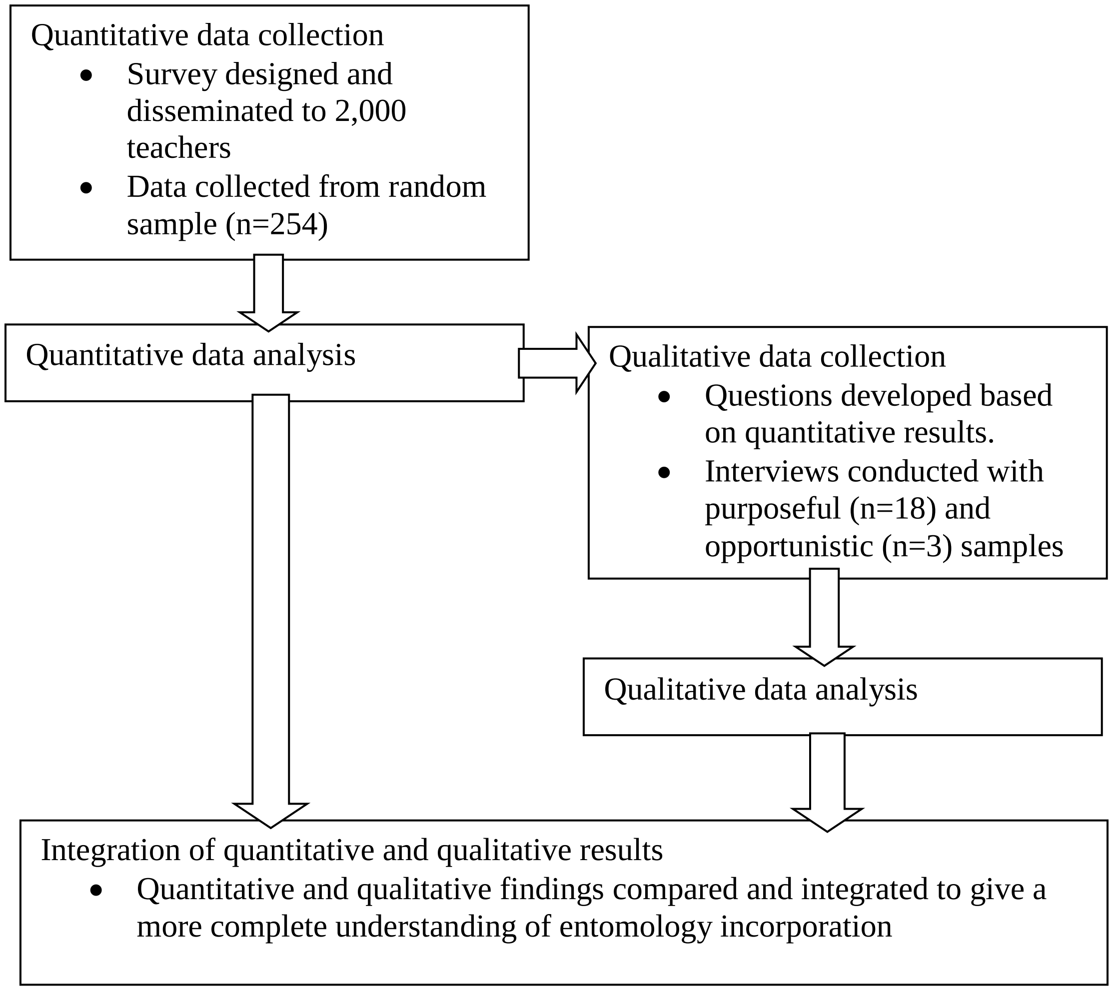

Figure 3.1. Sequential Quan → Qual research design for examining entomology incorporation in secondary science instruction.

Phase I: Quantitative Survey Research

The research objective of the quantitative strand was to characterize teachers' entomology education practices, beliefs, and attitudes in a representative sample of U.S. high school science teachers. Survey research was selected as a suitable research method as it provided a means of systematically 1) gathering information from a sample to identify descriptors of the larger population, 2) learning about people's behaviors and opinions, and 3) describing the basic characteristics or experiences of a population (Dillman, 2009; Groves et al., 2009). Based on financial and logistical limitations, a web-based distribution was selected as a feasible means of collecting data from a national sample of U.S. secondary science teachers.

Survey Development

A 24-item survey was created using the tailored design method (Dillman, 2009) and distributed via Qualtrics Survey Software (Provo, UT, USA). To minimize participant dropout due to fatigue, instrument length was kept to a minimum and the survey was estimated to take 20 minutes to complete. The survey included a single item asking for participants' consent to participate in the study (Appendix A) and the remaining items allowed for data collection on the following:

- Teacher background and demographics (8 items)
    - Gender
    - Age
    - Years of teaching experience
    - Courses taught
    - Grade levels taught
    - Educational attainment
    - Prior entomology education or experience
    - Contact information (if willing to participate in follow-up interview)
- Description of entomology incorporation practices (9 items)
    - Presence or absence of incorporation
    - Use of curriculum materials
    - Type(s) of insect(s) presented
    - Frequency of incorporation

  - Future incorporation intent
  - Entomology topics supported by incorporation
  - Science concepts supported by incorporation
  - Science practices supported by incorporation
  - Use of live animals including insects
- Barriers to incorporation (1 item)
- Teacher attitudes (2 items)
- Preferred resources to improve future incorporation (2 items)
- Perceived student benefit (1 item)

To maximize content validity (Creswell, 2012), four secondary biology teachers were selected as “experts” with applicable knowledge and experience related to insect incorporation and asked to pilot the survey items for clarity and content prior to implementation. The full survey is provided in Appendix B.

Sampling Method

A randomized sample of 2,000 secondary life science teacher email addresses were licensed from MCH Strategic Data (Silver Springs, MO, USA), a compiler of national education data for inclusion in the survey recruitment process.

Participant Recruitment and Data Collection

An initial recruitment email was disseminated to the recruitment pool of 2,000 potential participants over a three-day period. Two reminder emails were sent to all potential participants who had not yet completed the survey. The first reminder was sent one week after the initial email and the second follow-up was sent the following week.

All subjects were required to give their informed consent before they could participate in the study. The study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved on 1 April 2015 by the Ethics Committee of University of Nebraska–Lincoln institutional review board (IRB#20150415217 EX).

Data Cleansing

Prior to data analysis, we subjected all survey data to a cleansing procedure to remove responses lacking consent, providing insufficient information, providing contradictory information, or involving teachers who did not teach within the life sciences. The following data were removed prior to data analysis:

- Three respondents did not consent to participate in the survey.
- Four participants consented to participate but provided no survey data.
- Two participants responded that they did not incorporate insects, but later reported using live insects in their classrooms.
- One participant did not teach within the life sciences (P.E./Health instructor).

Data Analysis

Quantitative data were analyzed using IBM SPSS Statistics for Macintosh (Version 22; IBM Corp., Armonk, NY, USA). To characterize entomology incorporation, raw data (i.e. individual responses) were summarized as percentages, and descriptive statistics including frequency, rank, and mean were calculated.

Further inferential statistics were calculated to test for relationships between hypothesized factors of interest and different levels of entomology incorporation. First, factors of interest were selected based on prior research demonstrating the impact of 1) teachers' attitudes and beliefs, 2) use of curriculum and instructional supports, and 3) entomology experiences on teachers' instructional practices. Next, teachers' self-reported entomology incorporation practices were used to delineate "low" and "high" levels for different aspects of incorporation (Table 3.1).

Table 3.1. Determination of low and high entomology incorporation levels.

Aspect of Entomology Incorporation	**Incorporation Level**	
	Low	**High**
Frequency of incorporation reported	< once per month	> once per month
Number of insect types reported	0-4 insect types	5 or more types
Entomology topics reported	0-4 topics	5-9 topics
Science concepts reported	0-4 concepts	5-10 concepts
Science practices reported	0-4 practices	5-9 practices

Responses to factors of interest were also divided into categorical variables (Table 3.2). For each of the factors of interest, teachers' categorical responses were grouped as Yes or No, except for teacher beliefs and attitudes. For teacher beliefs and attitudes, five initial categorical choices (strongly agree, agree, neutral, disagree, and strongly disagree) were available in the survey. For cross-tabulation analysis, teacher attitudes and beliefs responses were condensed into three broad categories (i.e. agree, neutral and disagree) in order to satisfy the need for adequate numbers of responses in each response category.

Table 3.2. Determination of categories for factors of interest

Factor of Interest		**Categories**
Curriculum and instructional supports	Use of lesson plan	Yes/No
	Use of a self-created lesson plan	Yes/No
	Use of live insects	Yes/No
Teacher attitudes and beliefs	I am comfortable handling insects.	Agree Neutral Disagree
	I find the appearance of insects appealing.	Agree Neutral Disagree
	I have received adequate training to teach about insects.	Agree Neutral Disagree
	I am confident in my ability to teach about insects.	Agree Neutral Disagree
	I am capable of caring for insects in my classroom.	Agree Neutral Disagree
	I feel the cost of teaching with insects is affordable.	Agree Neutral Disagree
	I have time to teach about insects.	Agree Neutral Disagree
Teachers' prior entomology experiences	A college-level entomology course	Yes/No
	Professional development involving insects	Yes/No
	Other education experience with insects	Yes/No

To identify relationships between different levels of entomological incorporation and factors of interest, cross-tabulation analyses were performed. For each factor tested, a two-dimensional matrix was created to show response frequencies across two or more categorical variables (Table 3.3).

Table 3.3. Sample matrix used for cross tabulation analyses

		Entomology Incorporation Level	
		Low	**High**
Factor of Interest	**Yes**	Responses (Yes and Low)	Responses (Yes and High)
	No	Responses (No and Low)	Responses (No and High)

Respondent frequencies with the characteristics described by the corresponding row and column variables were recorded within the table. Marginals (totals) for each row and column were calculated and expected frequencies were computed as:

$$Expected\ frequency = \frac{total\ count_{column} \times\ total\ count_{row}}{n}$$

A chi-square statistic (χ^2) was then calculated to test if a statistically significant relationship exists between two categorical response variables (e.g. an aspect of entomological incorporation and a factor of interest). The chi-square value is computed as:

$$\chi^2 = \frac{(Observed\ Count - Expected\ count)^2}{Expected\ count}$$

If an association was apparent, Cramer's V was calculated to describe the strength of the relationship between the variables. Cramer's V was used to correct for an issue with measures of associations for tables of different dimensions (i.e. different numbers of categories in the two-dimensional matrix) and made it possible to compare the strength of any relationship across two cross classification tables (Gingrich, 1992). Cramer's V is defined as:

$$V = \sqrt{\frac{\chi^2}{nt}}$$

> where t is the smaller of the number of rows minus one or the number of columns minus one. If r is the number of rows, and c is the number of columns, then t = Minimum (r − 1, c − 1).

Phase II: Basic Qualitative Research

The research objective of the qualitative strand was to collect diverse teacher-centered perspectives on the practices, motivations, and perceptions that would contribute to a more complete understanding of entomology incorporation by elaborating or explaining quantitative results. Based on limited access to in-service teachers who incorporate entomology into their secondary science instruction, a decision was made to conduct follow-up telephone interviews with willing survey participants and face-to-face interviews with a select group of Nebraska science teachers with entomology incorporation experience.

Sampling Method

A purposeful sample of 18 total participants were selected for inclusion in follow-up interviews (see Appendix C) based on survey data indicating their willingness to participate in a follow-up interview. Among this sample, sixteen (16) participants fit the criteria for a high level of entomological incorporation and two (2) participants fit criteria for a low level of entomological incorporation. Participants representing these two groups provided confirming and disconfirming cases whose experiences could be used to test preliminary quantitative results (Creswell, 2012).

It was assumed that the selection of a purposeful sample made up of teachers demonstrating both high- and low-level entomology incorporation would provide diverse perspectives and allow for comparison of entomology incorporation experiences. To ensure that most participants would have a wealth of entomology incorporation experience to draw upon and would be able to provide insight into their commitment to incorporating insects or other arthropods into their science instruction, a decision was made that the majority of teachers purposefully selected for the qualitative strand would have reported a high-level of at least one aspect of entomology incorporation. In addition, a minority of participants reporting low-level incorporation practices would be selected to provide their unique perspective on incorporating entomology in a limited manner.

In addition to selecting confirming and disconfirming cases for follow-up interviews, opportunistic sampling (Creswell, 2012) was employed to identify three (3) secondary science teachers within the state who had experience incorporating entomology in their classrooms and who were willing to provide additional in-depth interviews.

Semi-Structured Interview Question Development

Based on the sequential mixed methods design, the purpose of the follow-up qualitative strand was to elaborate, explain, or confirm results from the quantitative strand. Findings from the quantitative strand of this study provided the foundation for the qualitative follow-up interview questions (For a complete analysis of the quantitative strand, see Chapter 4).

In the follow-up qualitative interviews with survey participants, open-ended questions were developed (Appendix E) which allowed for emergent teachers' perspectives to be placed at the forefront rather than imposing the primary researcher's a priori framework (Table 3.4). Additional open-ended questions were developed (Table 3.5) for use with an opportunistic sample of local secondary teachers with entomology incorporation experience who were willing to provide more in-depth interviews as the study progressed. The questions were designed to elicit rich descriptions of teachers' entomology incorporation practices and motivations, and to explore teachers' preferences for curriculum materials and instructional supports (Appendix F).

Table 3.4. Connection between quantitative results and development of qualitative interview questions

	Quantitative findings to be explored	**Goal of qualitative analysis**	**Qualitative interview questions developed**
RQ1	Characterized how insects support science concepts, science practices, and entomological literacy	Elaborate on how insects support science instruction from teachers' perspectives	• What "big ideas" do you want your students to understand about insects when they have left school? • Do you help students connect the impact of insects to their daily lives? If so, how? • I would like you to recall a time when teaching about insects in your classroom was especially effective. • How were insects used to support science concepts or practices? • How did the use of insects help to improve student understanding or engagement? • How and why was this particular lesson so successful?
RQ2	Identified factors associated with higher levels of entomology incorporation	Elaborate on classroom realities that support or hinder entomology incorporation	• How did you get started teaching about insects in your classroom? • What factors made insect incorporation possible? • Why did you choose to incorporate an insect in this lesson?
RQ3	Identified standards-aligned lessons plans as the preferred resource identified by teachers	Explain how standards-aligned lesson plans meet teachers' needs	• Where do you go to find quality lesson plans? • What elements do you look for in a high-quality lesson plan? • How would providing you with a lesson plan help you to incorporate insects into instruction?

Table 3.5. Additional qualitative questions asked of opportunistic cases

	Goal of qualitative analysis	**Opportunistic qualitative follow-up questions**
RQ1	Elaborate on purpose of insects in supporting science instruction	• What purpose do you think insects serve when using them in your life science classroom?
RQ2	Elaborate on importance of teachers' prior entomology experiences	• Can you tell me about any formal or informal entomology experiences or training that you have that make it easier to teach with insects or insect-related materials? • What challenges, if any, make it difficult to incorporate insects into your instruction?
RQ3	Elaborate on supports for teachers with limited entomology background or incorporation experience	• What important information or advice would you share with a science teacher who wants to include insects or insect-related materials in their classroom?

Data Collection

Data were collected from follow-up interviews with survey participants by the primary investigator (Ingram) via telephone between 10 August 2015 and 2 October 2015. All subjects were required to give their informed consent before they could participate in the study (Appendix D). Respondents were asked to participate in a 30-minute interview. All interviews were digitally recorded.

Data were collected from in-depth interviews with three local secondary teachers with entomology incorporation experience by the primary investigator. Respondents were asked to participate in a 30-minute interview. All interviews were conducted during face-to-face meetings between 8 August 2017 and 25 March 2019 and were digitally recorded.

Additional secondary data sources included video recordings of classroom instruction in which entomology content was presented, field notes, student interviews, and curriculum artifacts such as lesson plans. Informed student assent and parent consent (Appendix D) were acquired from all participating students and their guardians prior to data collection. The study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved on 31 May 2017 by the Ethics Committee of University of Nebraska–Lincoln institutional review board (IRB# 20170517174 EP).

Data Analysis

All interviews were transcribed for analysis by the primary investigator or a transcription service (Rev.com; San Francisco, CA). When transcription was completed by professional transcriptionists, appropriate confidentiality agreements were obtained.

All transcripts were entered into ATLAS.ti, a computer-aided qualitative data analysis software (ATLAS.ti Scientific Software Development GmbH; Berlin, Germany), as separate documents. Qualitative data analysis software provides a means of organizing and retrieving data for efficient comparison and analysis but does not conduct qualitative analysis independently (Merriam, 2009). Atlas.ti was selected as the software tool for qualitative analysis based on its ability to analyze text and multimedia data sources and its networking capability allowing for codes to be visually sorted into categories during thematic analysis.

Analysis was conducted in two key phases: open coding and analytical coding (Merriam, 2009). During open coding, meaningful data segments which provide an answer to the research question are identified in the interview transcripts and codes made up of the participants exact words, the investigators’ words, or concepts from the literature are assigned to the data segments (Merriam, 2009). During the subsequent phase of analytical coding, codes are sorted into related themes or categories (Merriam, 2009). Data analysis will begin as an inductive process in which data segments are discovered and descriptive codes are created, compared, and grouped into categories based on the investigators' interpretation and reflection on meaning of patterns in the data. However, analysis will shift to a deductive process as categories are tested and confirmed or disconfirmed as new data are examined.

In this study, data analysis for each qualitative research question was conducted by the research team consisting of the primary investigator (Ingram) and secondary investigator (Golick). First, the primary investigator conducted a preliminary analysis of interview transcripts to become familiar with the data. Next, open coding was conducted with the first few transcripts in which descriptive codes were created based on what the investigator observed in the data. During this phase of analysis, an initial code list was constructed for each of the three qualitative research questions. To determine the clarity of the initial code list, the secondary investigator applied the initial codes to the same sample of interview transcripts. The research team then compared coded transcripts, discussed discrepancies in application of codes to data segments, and refined the initial code list for clarity. During this process, the research team agreed to apply codes to whole paragraphs rather than sentences or phrases to allow for ease of reviewing inter-rater agreement. Iterations of creation and application of codes and comparison of coded transcripts were repeated with additional interview transcripts. Additions or refinements were made to the initial coding list based on analysis of new data to create a master code list for each qualitative research question. Once the research team felt that no new insights or understandings were emerging from the data, the primary investigator engaged in analytical coding in which codes from the master code list were grouped into broader themes based on patterns identified in the data (Merriam, 2009). Lastly, primary investigator analyzed the remaining interview transcripts using the thematic codes and coding was checked by the secondary investigator.

To ensure that themes were sufficiently grounded in the data, a feature in Atlas-ti was used to quantify the number of data segments which were coded with each of the themes or categories. Only themes that were grounded in at least five data segments were included in the qualitative findings (see Appendix H).

Data Validation

All research aims to contribute valid and reliable knowledge to the scientific literature while adhering to ethical standards (Merriam, 2009). In the case of qualitative research, the goal is not to capture objective "truth" or "reality", but to portray credible and accurate representations of participants' constructed reality (Merriam, 2009). To increase credibility of findings, several different strategies were employed including triangulation, rich description, and reflexivity.

Triangulation. Creswell (2012) describes triangulation as "the process of corroborating evidence from different individuals, types of data, or methods of data collection in descriptions and themes in qualitative research" (p. 259). In this study, evidence was triangulated in several ways. First, multiple data collection methods were used including conducting interviews, making field observations, and gathering documents. Next, data from multiple sources were checked against one another for consistency. Lastly, investigator triangulation was employed in which two researchers analyzed the same data separately and findings were compared (Merriam, 2009).

Rich description. In presenting vivid, detailed findings and adequate evidence, readers are supported in determining if findings can be extrapolated to other settings (Merriam, 2009). To maximize transferability, quotations and examples presented in this study provide rich, thick description of the setting, participants, and findings.

Reflexivity. In qualitative research, the investigator acts as the research instrument and thus is not able to remove him- or herself from the analysis. However, to better explain how the researcher arrives at a given interpretation of the data, reflexivity is a strategy that calls upon the investigator to reflect on and report their biases, dispositions, and assumptions (Merriam, 2009). The primary and secondary researchers both have a formal entomology background which influences their perceived beliefs about the importance of insects and the need for an entomologically literate public. In addition, the research team possesses familiarity with formal classroom expectations and protocols due to the primary investigator's prior training as an elementary education teacher and current full-time position as a K-12 STEM curriculum developer and the secondary investigator's experiences engaging high school students in a citizen science project related to bumble bee research and conservation. A discussion of the philosophical foundations that guided the design and implementation of this research study is provided in the introduction (see Chapter 1).

Ethical Considerations

In order to protect research participants' rights, all participants were asked to read and sign an informed consent form approved by the IRB (Appendix D) prior to their participation in the study. To protect participants' confidentiality and anonymity, participants were assigned a code during their interview and any identifying information or background was removed prior to presentation. Due to the non-sensitive nature of the study in examining teachers' practices, beliefs, and attitudes toward entomology incorporation, it was determined by the research team and the IRB that the study posed minimal risk to participants and that involvement would have no negative impact.

When transcription was completed by professional transcriptionists, appropriate confidentiality agreements were obtained. All audio files and transcripts were stored digitally on a password-protected computer accessible only to research team members. Printed copies of the transcripts were stored in a locked filing cabinet accessible to the primary investigator. The transcriptions will be kept no longer than five years beyond completion of this study.

CHAPTER 4: FINDINGS AND RESULTS

RQ1: How can entomology incorporation be characterized in U.S. secondary science instruction?

Quantitative Results

Accuracy and representativeness of sample. Survey data were collected from an initial sample of 264 survey participants. Data from ten participants were eliminated during data cleansing, resulting in analysis of survey data from 254 secondary science teachers (12.7% response rate). Most participants (73%) completed the survey in 10-20 minutes. Survey data were collected from teachers in 41 different states in the U.S. California, Texas, Maryland, Pennsylvania, Wisconsin, and New York were the top six most represented states in the survey.

With an estimated 59,163 total high school biology teachers in the U.S. (Blank, Langesen, & Petermann, 2007), the reported percentage estimates have a margin of error of 6.1% at the 95% confidence interval based on a standard calculation for margin of error (Dillman, 2009, p. 56).

A comparison was made of participant demographics to U.S. natural science teacher demographics (U.S. Department of Education, National Center for Educational Statistics, 2015b) to determine if the survey sample was representative of the population of inference. Based on these comparisons (Table 4.1), the survey sample included slightly more women (7% more than average), and participants tended to be older (18% more than average are 40 years or older), more experienced (22% more than average with 10 or more years of teaching experience), and more educated (15% more than average with a masters or doctorate degree) than the overall population of natural science teachers.

In addition to comparing teacher demographics of the sample to national averages, school demographics of the sample were compared with national averages. The sample was over-representative of suburban schools (9% more than average) while slightly under-representative of schools in rural areas and cities (-6% and -3%, respectively). In addition, public schools were slightly overrepresented in the survey sample (+12%) compared to private schools when compared to national statistics (U.S. Department of Education, National Center for Educational Statistics, 2015a).

Table 4.1. Comparison of survey sample to U.S. teacher and school demographics

	Demographic Criteria	**Demographic Characteristics**	**National Natural Science Teacher Population**	**Survey Sample**	***n***	**Difference**
Teacher Demographics	Gender	Male	45%	38%	84	−7%
		Female	55%	62%	135	7%
	Age	Under 30	16%	6%	13	−10%
		30–39	30%	21%	46	−9%
		40–49	26%	29%	64	3%
		50–59	22%	33%	73	11%
		60 and over	7%	11%	23	4%
	Years Teaching	<3 years	10%	6%	11	−4%
		3–9	34%	15%	29	−19%
		10–20	36%	44%	86	8%
		>20 years	21%	35%	68	14%
	Degree Earned	<Bachelors	3%	0%	0	−3%
		Bachelors	36%	28%	61	−8%
		Masters	52%	64%	139	12%
		Doctorate	4%	7%	15	3%
		Education Specialist	6%	2%	4	−4%
School Demographics	Locale	City	26%	23%	48	−3%
		Suburb	27%	38%	81	9%
		Town	14%	14%	29	0%
		Rural	32%	26%	54	−6%
	Public/Private Designation	Public	75%	87%	181	+12%
		Private	25%	13%	27	−12%

Characterization of entomology incorporation in secondary science instruction. Most teachers (88%) in the survey sample reported incorporating insects into science instruction to some degree within a typical academic year. For the purposes of this survey, entomology incorporation was defined as "presentation of or interaction with any media depicting an insect such as a picture, video, audio, text, lecture, discussion, activity, lesson, pinned specimen, or live insect." Teachers presented a variety of different insect types (Figure 4.1) with an average of 5.27 ± 0.26 SE insect types used. When "other insects" were reported, popular responses included other arthropods (n=16) including isopods, centipedes, millipedes, mites, or ticks; aquatic insects (n=12) such as caddisflies, mayflies, dragon- or damselflies, or stoneflies; and walking sticks (n=6).

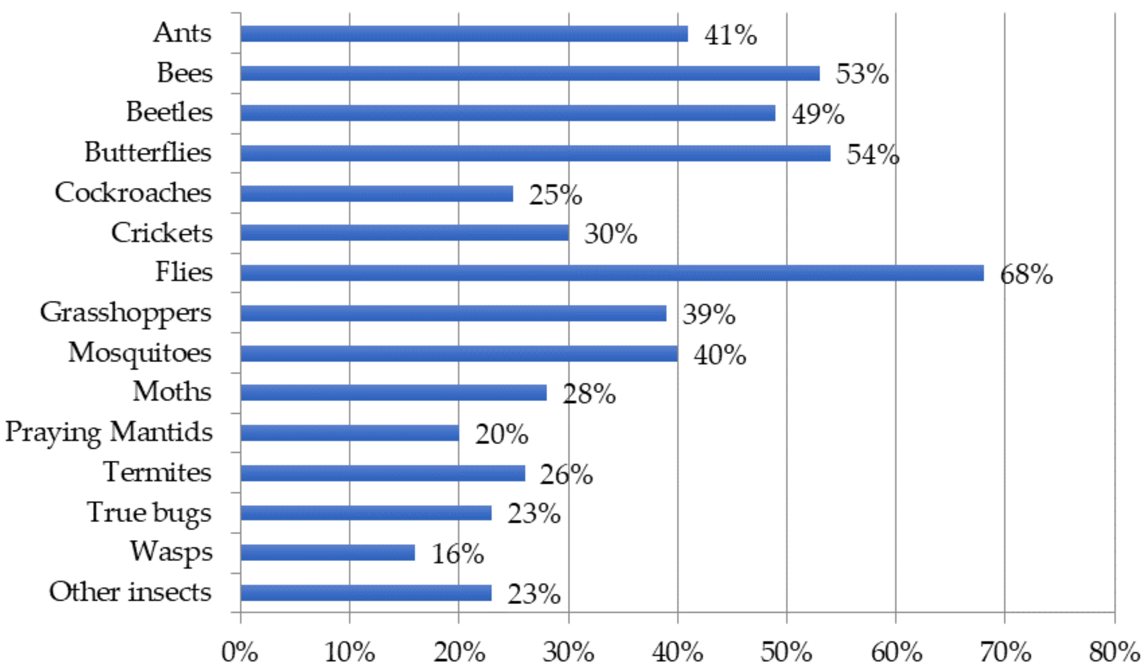

Figure 4.1. Insect types incorporated

Results indicate that 65% of respondents reported incorporating entomology content less than once a month during the academic year (Figure 4.2).

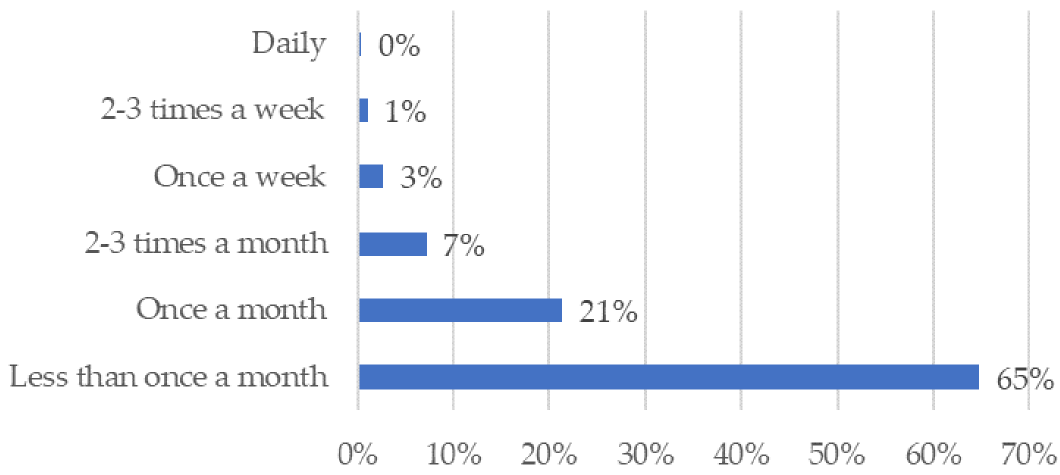

Figure 4.2. Frequency of insect incorporation

To determine if students were being exposed to important entomology topics, we used findings from Pearson, Skinner, and Hoback (2007) as a reference for what students should know and be able to do relating to entomology by the time they have completed grades K-12. Presentation of entomology content supported students learning about insect-related topics with ecosystem functioning, impacts on human health, and insects' role in agriculture and our food supply being the most common topics covered. In contrast to popular topics, aesthetic value of insects, the decision-making process of considering the costs and benefits of insect pest control, and the value of insect products were introduced least often (Figure 4.3).

The recently revised Next Generation Science Standards (NGSS) (NGSS Lead States, 2013) was used to guided identification of cross-cutting concepts and disciplinary core ideas which are commonly covered in life science instruction and scientific practices in which students would likely be engaged. While the NGSS were not adopted by all U.S. states at the time of this survey, the standards provided a current and popular framework of reasonable expectations for what students would be learning about and doing in science courses. More than 75% of teachers indicated entomology incorporation supported student engagement in observation, encouraging students to ask questions, analyzing or interpreting data, and evaluating and communicating information (Figure 4.5). Science practices such as developing and using models or engaging in argument from evidence were newly added to the revised standards in 2013. The relatively recent focus on these practices may partially explain why entomology incorporation is not yet supporting these practices to a greater extent.

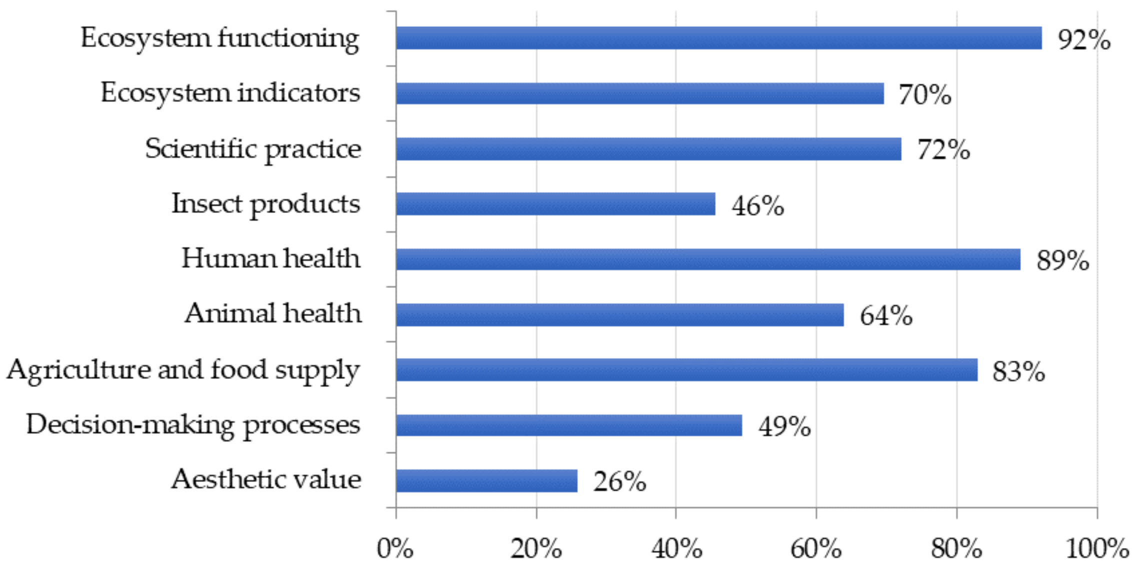

Figure 4.3. Entomology topics supported by entomology incorporation

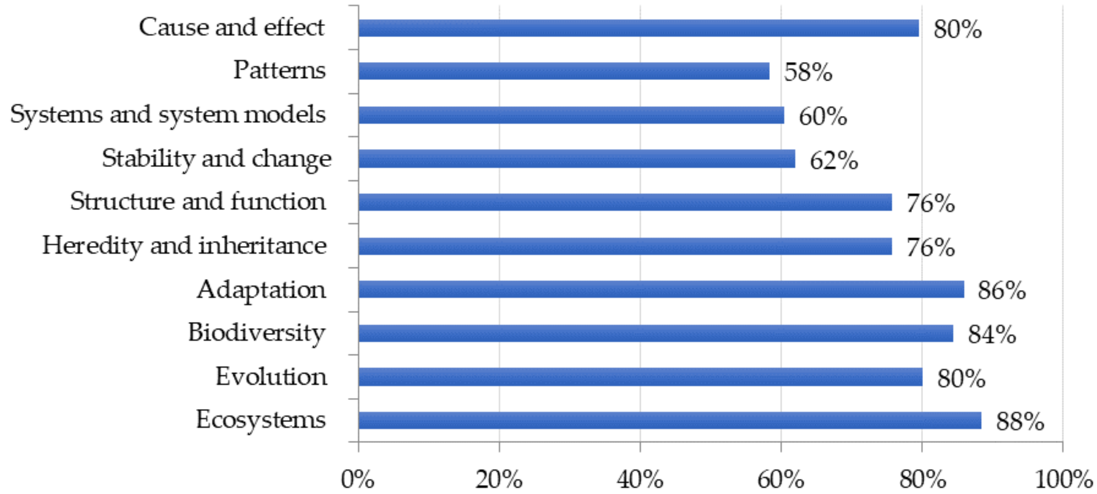

Figure 4.4. Life science concepts and core ideas supported by entomology incorporation

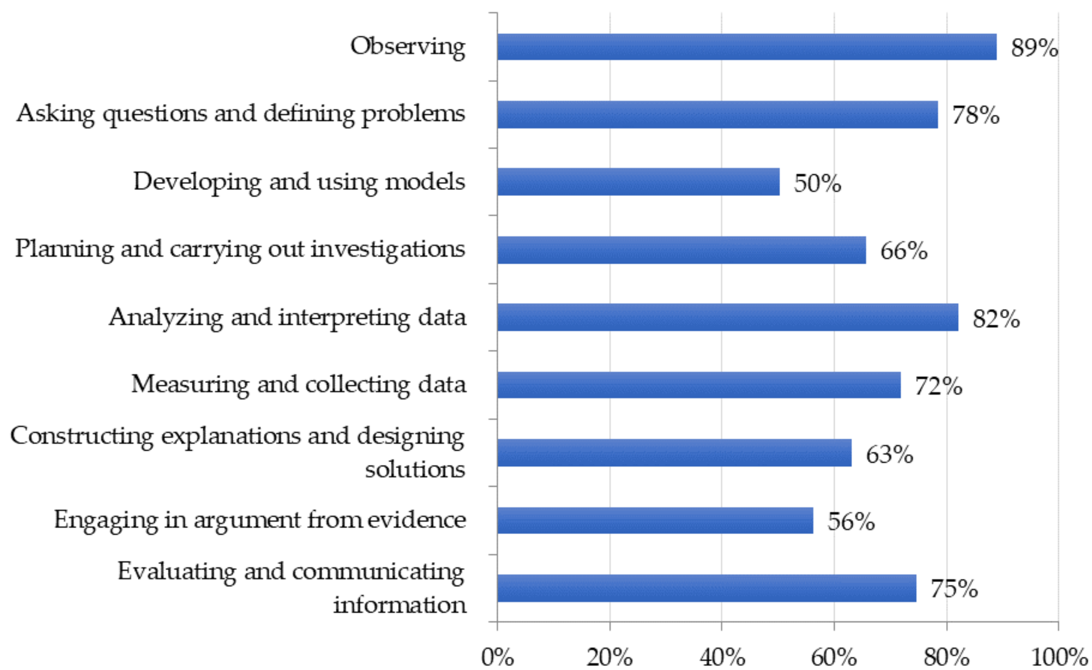

Figure 4.5. Science practices supported by entomology incorporation

Instructional resources. Lesson plans were used by 81% of teachers and nearly half of all teachers (49%) reported creating their own lesson plans. Lastly, 61% of teachers reported that live animals were used during science instruction. Within the sample of teachers using live animals, popular animal groups included insects (71%), non-insect arthropods (42%), fish (29%), reptiles (21%), amphibians (19%), annelids (19%), mollusks (14%), mammals (12%), cnidarians (9%), planarians (7%), birds (6%), and nematodes 2%).

Qualitative Findings

Results from the quantitative strand indicated which entomology topics, science concepts, and science practices teachers believed to be supported by incorporating insects into science instruction. However, in follow-up interviews, teachers described a variety of outcomes in addition to disciplinary content knowledge or science skills that resulted from entomology incorporation practices. These outcomes became the focus of the qualitative analysis to answer the question, "What perceived outcomes do secondary science teachers associate with incorporating entomology into their science instruction?" Findings from this analysis were consolidated into two themes: educational outcomes and emotional outcomes.

Educational outcomes. Unsurprisingly, entomology was presented in the classroom to support educational outcomes including learning about science content and engagement in science practices. These findings are in alignment with results from the quantitative strand. However, findings from teacher interviews allowed for a more nuanced understanding of educational outcomes of importance from teachers' perspectives.

Illustrating key science ideas with insect examples or models. As one participant so eloquently explained, "every living thing is a microcosm of all living things". This statement was echoed by numerous other teachers who described using insects as "examples" or "models" of science concepts or core ideas. In one example, a teacher recounted students’ reaction to a Madagascar Hissing Cockroach as a good illustration of the effectiveness of defense mechanisms.

> “They love the hissing. When they get really quiet and I'm like, "Okay, I'm going to agitate him or her. See the little holes on the back? They're going to compress air through the spiracles and they're going to make a little hissing sound. Then, I agitate the back and it goes, "Shh Shh," and the kids go, "Huh!" (scared or fearful sound) I'm like, "Guys, there's 30 of you and it's one little cockroach. You see how powerful this defense mechanism is? You are so much bigger than him or her. You could just crush them but look how scared you are. Don't you think that's a really cool adaptation it has?" They're like, "Wow, yeah!”

Another teacher explained how some science topics may have limited meaning to students’ lived experiences, but that live insects can provide a bridge connecting abstract science topics with tangible connections to their lives outside of school.

> “Well, I think, you know, we talked about invasive insects in the past, and invasive plants, and I don't think, you know as 9th or 10th graders, they don't really understand what that means to them. They don't really have any concrete examples, so when you show them an insect and you explain, you know, hey this could be in your backyard, this could be in your town, and then we take them to some of these places with these people and we show them what these insects have done for damage, then they can really connect it right to their own neighborhood.”

Some teachers explained that live insects make science “real as opposed to a picture or a description in a textbook”. One teacher described the importance of visceral experiences with living insects as a memorable tool for illustrating otherwise uninteresting content.

> "It irks them so much that they need to understand. It's the same way with these insects. If I can give something to that kid that they haven't seen before and it helps illustrate what I'm talking about on the board, that kid is going to love that. They're going to understand it and they're going to remember it. If I just go up here and I put up a PowerPoint or pull something off the internet and it's just up here on the board or it's in their book, it isn't actually like seeing it happen."

Engaging in science practices. Scientific practices are described as "the major practices that scientists employ as they investigate and build models and theories about the world" (National Research Council, 2012, p. 30). In much the same way that interactions with live insects supported the learning of key science ideas, nearly all teachers discussed how students' experiences with living insects were closely tied to engaging in the work of scientists. Making an insect collection, dissecting insects, sampling or surveying insect populations, and planning and/or conducting experiments with living insects were commonly mentioned.

Not all interactions involving live insects necessarily support students in doing the work of scientists. However, in cases where teachers adopted a student-driven approach, it appeared that students were more readily able to step into the role of investigator. One teacher expressed how the use of entomology field studies was an especially effective means of engaging students in practices that are commonly used in taxonomy (i.e. collection, observation, identification, and classification) and becoming comfortable with scientific tools such as a dichotomous keys, dissecting microscopes, and insect collecting equipment.

> "I think the most effective lessons I have had about teaching about insects was when I lived in [redacted] and we spent a lot of time creating those field study pieces that our kids did, and teaching them how to actually work in the field, actually taking them out and letting them do the collecting and then bringing things back and looking at them under the dissecting microscope, and teaching them how to use the dichotomous keys. I think those were some of the most effective lessons I had because I could incorporate the taxonomy, I could incorporate what it means if you want to study those kinds of organisms, what it takes to do that kind of field work, the patience it takes, and then I could incorporate that into taxonomy and dichotomous keys, and just so many other things into that one activity that started with taking them out in the field and letting them collect."

Various research projects also provided opportunities for students to plan and/or conduct experiments using live insects. Teachers reported students "researching how to rear insects" prior to "conducting experiments". In other cases, serendipitous events such as population fluctuations of lab-reared insect colonies provided opportunities for students to "watch the population increase … then we will find a whole bunch of dead ones and the population will level out and we can graph".

In cases when students had higher levels of autonomy, a greater number of scientific practices were described. For example, a teacher explained how students conducted experiments related to inherited traits using fruit flies.

> "They didn't design their own in this case, which I could have had them do. It was a prescribed experiment, but they conducted it themselves, they did their own

> observations, they got to see the patterns and the life cycles, and we talked about how that's repeated with lots of insects throughout the world, their life cycles. Another science practice would be analyzing the data and making the connections to inherited traits. They also did statistical analysis on the data."

The teacher went on to explain the value of this approach and how it differed from more traditional instruction, "It's not just doing a genetics problem. They're dealing with real data that they observe, and I think that makes a huge impact."

Developing students' critical thinking skills. In several cases where teachers supported more open-ended inquiry, the use of live insects functioned as a vehicle for student-driven investigations that resulted in critical thinking and problem solving. Teachers often explained that "student-focused" instruction led to a "high level of engagement" and resulted in a successful learning experience. One teacher explained how ceding some instructional control and offering limited guidance led to an engaging entomology experience for a group of juniors and seniors.

> "Well, when the students first came up with the idea. I didn't want to be the person that told... there's a thing in high school science that I don't know if they use it in the university. There are two kinds of laboratory experiences what they call guided inquiry and free or open inquiry. Well, I wanted the kids who wanted to do this to experience an open inquiry kind of laboratory. So, I made it so that they would figure out everything that they had to do. So, I basically guided them in that they needed some kind of insect that you could store over the winter and then you would have to go in the spring to the middle school and so on. So, in terms of engagement, the people that volunteered to do this, the team, they did

research online, they found in the catalog what you could do, and we made some suggestions and so on. I would say challenging them just with the problem, and then saying, "Solve it. And you have basically two or three months to do it. And you can do it at your own time and your own speed." And we just set up meetings every once in a while. I would say that that was a very engaging experience for them."

The teacher went on to recount, in great detail, how students engaged in "practical" problem-solving when facing the unstructured challenge of rearing insects.

> "And in terms of engagement and so on, I don't remember the particulars, but when you are researching how to rear these insects, there's a kind of seed that you feed them, you know, when you don't have milkweed, and the kids had gone and gotten the seeds, but they were the wrong thing. I'm forgetting which one it is, they were either pumpkin seeds and they should have been sunflower seeds, or they were sunflower seeds and they should have been pumpkin. It was something... but they weren't eating the seed, so the adults and nymphs were dying off all the time. And then they figured it out so that was like a good thing."

Even experienced teachers can struggle to plan and implement unstructured or open-ended inquiry which may help explain why this outcome was relatively uncommon among participants.

Addressing misconceptions. It has been said that we fear what we do not know and in the case of entomology, this may well be the case. Teachers regularly pointed out that insects are often "overlooked", "not something that they see all the time", and that students "don't learn a lot about insects in many other units or many other classes".

Unsurprisingly, teachers reported that many students hold negative perceptions of insects including “being afraid”, “frightened”, and “creeped out” and that these perceptions are tied to students’ ideas about insects being “gross”, “dirty”, “bad”, and “scary”.

Along with being overlooked and generally disliked, teachers reported that students often held “misconceptions”, “false assumptions”, or “misunderstandings” about insects and other arthropods. Common misunderstandings included the belief that most insects are bad or harmful and that many different types of insects are “all the same”. One teacher reported that his students held a particularly striking misunderstanding. They did not believe that insects were animals.

> “One of the biggest misconceptions that I would say all of beginning biology students have is that, you know, there's three, there's maybe... Well, you point out that there's bacteria and stuff, but then they go, "Okay, there's four kinds of living things. There's bacteria, animals, plants, bugs”. They think they are their own things. They think, you know, animals are the fuzzy dogs and cats and things, and they really associate mammal with animal and insect is insect but it's not animal.”

Many teachers indicated that they hoped by teaching about entomology they could counter students’ misconceptions about insects. As one teacher explained, “I just like to dispel the misunderstandings and misconceptions and explain to them the importance and the goodness of the insects”. In presenting entomology in a formal education setting, one teacher explained that student understanding or engagement was improved by “expanding the limits of what they think is possible in biology.”

Making content memorable. Four teachers indicated the importance of student learning from a long-term perspective. One teacher described how striking it was to younger students when older students could recall knowledge of insect classification.

> “It's the individual investigations in finding things out and then knowing things later, being able to identify things after the fact, that they still remember. You don't always get them so that they remember everything, like my older students will even come back as the younger students start doing it and say, "Oh yeah, that's a Coleoptera" and these are kids not necessarily even interested in science. But they will go in and then, the younger kids are all impressed because "These guys still know this stuff."

Another teacher explained that it was difficult to gauge the success or failure of a lesson in the short-term, but that seeing evidence that learning was retained or remembered in the long-term was a better measure.

> “I don't know that you know how successful it is. It is self-successful. But when kids come back a year later and say that they remembered. And I think that it takes your breath away when you realize that you've impacted someone like that. And when somebody comes back and tells me "That day that we looked at that grasshopper…" I mean, that measures the success of your lesson. I don't know that I could measure it quantitatively, like with better success on a standardized test or something. I don't know that that's something that I could do but when a 30-year-old man walks up to you and tells you that they still have some piece of your lesson, you succeeded.

Several teachers explained that it seemed that the topic of entomology or perhaps the presentation of living insects piques students' interest. One teacher felt that connecting content to a memorable insect model was particularly effective.

> "If they go back to it. Whenever they're trying to explain the concept of natural selection and how the environment affects, they always go back to that moth."

Another teacher found that Wolbachia, a topic related to entomology, provided a puzzling phenomenon to explore.

> "I found that the Wolbachia project, the infection of the insects, is interesting to students. It's something that's new, and it's something that intrigues them, so they want to learn more about it. So, it makes them remember something about the skills, and why they were using them. But it needs to be interesting, otherwise it just becomes these skills that they don't connect to anything real, and they don't remember anything about."

Connecting the classroom to the real world. Many teachers described ways that insects could be used to connect science instruction to the real world. The use of local outdoor environments for conducting science was commonly reported. Teachers saw entomology incorporation as an opportunity to make science instruction "more than sitting at a desk and reading a textbook". The practice of "going outside and collecting insects" was viewed as "doing real-world science" like "a scientist would do if they were trying to look for a new species". In some cases, teachers leveraged students' personal interest in being outdoors to focus greater attention on the insect biodiversity available in the immediate area.

> "You know it's just a unique thing that because, when you are 14 or 15 years old you typically don't go out and look at the different types of insects that are out there. And look at the variety. So when they start seeing all of the stuff that's out there it's just for some kids, it's like "whoa, I had no idea that this was even in my yard, and these kids, we are in northern [redacted], they are used to being outdoors and doing things and that kind of thing, but they are looking at big stuff and not little stuff and so it's kind of exciting to see these different things that are right in their backyard."

Interestingly, a teacher's desire to teach students that insects are ubiquitous and a natural part of the environment could have unintended consequences. In several cases, teachers described their decision to release commercially available insects or other arthropods into environments from which they did not originate. One teacher explained getting an order of pill bugs "shipped in" for use and later releasing them into the nearby environment during a "release party".

> "The students and I took the pill bugs and we were able to release them into the environment, right into the pond area, and it was something that was very, I said to the kids, "Look, they're part of our environment, they live here," and I really tried to stress with them that, "They're here for us to use, and then as soon as we're done using them, we need to return them back to the environment."

Another common real-world connection that teachers highlighted was the current and future impact that insects have on local economies and livelihoods with special attention being paid to agriculture. One teacher focused on the positive impacts that pollinators have on orchard fruit production.

> "Because it's all around and I don't think that the kids, I don't think that most of them understand that there is a connection between the orchard... the bees and the apples. Even though they live right here in the same town with them. Just to help them understand that there is a reason that they truck the bees in and, you know, that they put them in various places in the orchard and they rely on them to make the crop"

However, other teachers focused on negative impacts that species of pest insects have on agriculture crops.

> "Well, we do have an issue with an insect here where I live, and it's the Psyllid that carries that awful citrus greening disease, and we do talk about that and how insects can be invasive species as well, or introduced species, I should say. In that sense, it's probably that would affect their daily lives especially here because many, many families depend on the citrus industry for a living, including me. I'm a citrus farmer. We are scared to death of this disease. It would just wipe us out."

One teacher pointed out how knowledge of entomology as it relates to agriculture is culturally embedded, but that not all students may be aware due to a lack agricultural experience or interest.

> "We live in a farming community. A lot of the students are farmers. I've been in the farming industry one way or another. Pests and these things and just identifying insects is always been part of our culture to some degree and I just brought that out more so for students who weren't farmers or into that, just awareness of their significance not just in farming but in all ways."

While some teachers focused on the relevance of insects to the local economy broadly, others chose to use insects to highlight career connections and future job prospects that might be of personal interest to students. In one teacher's vocational horticulture class, the presentation of entomology topics directly served students' need for knowledge they could put to use in a professional setting.

> "And a lot of our students go out on co-op jobs at actual landscape companies and garden centers and a lot of them were really excited because after we learned about it, some of their employers asked them, you know, in the field how would you spot the hole that they've entered in the tree. And they knew all of that, so they were pretty excited that could connect it to their job and their employer saw the value in it.

In another instance, the teacher described using insects as means of raising career awareness rather than vocational training.

> "I think that probably happens the most through the beekeeping, so they can see ... For one, we do a lot of connection with careers, so they can see that beekeeping could be a viable career."

Emotional outcomes. In addition to educational outcomes, most teachers described emotional outcomes they felt were associated with incorporation of insects in their science instruction. While teachers overwhelmingly focused on emotional outcomes for students, some teachers also discussed emotional outcomes for themselves.

Being excited to learn. Given the generally negative public perception of insects, it may seem surprising that most teachers described students as being "excited" or "enjoying" science instruction involving insects. However, as teachers previously pointed out, insects are commonly “overlooked” and “misunderstood”. It may be students’ lack of entomological awareness or understanding that leads teachers to describe insects as an “awe factor” or “wow factor” that elicits students’ “surprise” and “interest”. One teacher explained how students’ surprise, curiosity, and excitement influenced their learning about a bacterium known as Wolbachia and its effect on insect reproduction.

> “It gets students so excited, because we start talking about things like parthenogenesis, and before they even know what it is, they're like, "Oh my god, that's cool. I want to know more about that." They get really excited and interested. Then that leads to us going outside and collecting insects.”

The teacher went on to explain the importance of “new” experiences in capturing students’ attention and supporting curiosity.

> “I found that the Wolbachia project, the infection of the insects, is interesting to students. It's something that's new, and it's something that intrigues them, so they want to learn more about it.”

In some cases, it was difficult to determine if positive emotional outcomes were directly affiliated with insects or with outdoor spaces where insects reside. Some teachers explained that being outside was a source of student happiness, especially in areas where cold weather prevents conducting class outdoors for much of the academic year.

> “It's awfully cold and winter lasts from about the end of October to the end of April, so if you can get them out in the fall, in September, October, or you can get them out in the Spring, in April and May, everybody's happy because you finally got outside, so that's kind of part of why we used them up there. It gave us that opportunity to get out, take the kids out, let them experience what life was in the

field and it was also a good follow up. It was kind of a follow up on that just those things that can get them out of the classroom and someplace different and more exciting."

Overcoming fear/disgust. Students' negative emotions in response to insects such as fear or disgust were not commonly mentioned, however, some teachers recognized that not all students perceive insects positively. As one teacher described the polarizing nature of insects, "You know, some kids like them and some kids don't". Despite some students' initial reticence or outright dislike of insects, a teacher described how students' perceptions of insects would change over time.

> "It's interesting because everybody in the room will participate at different depths. So, some people just don't even want to look at them. They're freaked out, they're in the corner of the room, they've got their hands up in from of their faces. And then other people, they just want to come over and see as much as they can. They want, "Hey, how did you do that? How did you get this?" So, there's this continuum of participation and when the kids who are afraid in the corner see that the kids who are interested are not getting skeeved out or hurt, they come over and the fence-sitters start to jump onto the right side of the fence."

In cases where students overcame an initial negative emotional response to an insect, some teachers described students as "proud" of themselves or "feeling brave". Teachers credited hands-on interactions with insects as responsible for students' positive emotional shifts. One teacher described a yearly ritual introducing students to Madagascar Hissing Cockroaches as a "special moment" for its ability to impact students' emotionally.

> “The special time is when a student realizes, "Huh, it's not that bad," and they overcome a fear, because they're educated, and they maybe are brave enough to maybe touch or observe to the point of feeling the exoskeleton. Then, they realize, it's just a living thing. It's like a pet. It's just an animal. It's okay and they're not gross.”

Developing empathy/care/concern. **S**everal teachers pointed out how incorporating entomology into their science instruction supported students in developing a sense of empathy for insects and other arthropods. Teachers described students as exhibiting empathy when they showed “concern” that insects were “taken care of” and would “check in on” insect colonies in the classroom. One teacher recounted how five students were especially concerned with the well-being of pill bugs being reared for classroom experiments.

> “I think the five girls kind of adopted, almost, the pill bugs. Some of them would even come in the morning and they would help me change out the soil and they'd be ... I had one girl who would bring in lettuce, she would bring in lettuce for me to lay in the tank.”

Teachers explained that hands-on interactions especially with living insects in which students were responsible for caring for the insects were a key element in students developing empathy. One teacher highlighted the difference between students being exposed to hands-on experiences with preserved specimens versus living insects.

> “I think in biology classes most kids are exposed to, "I'm doing a dissection." The animals are already dead. Here we have something that we were taking control of, so they kind of had to take control of the situation. They were dealing with

> something that was alive. They were very, "Oh, we have to be very careful with these organisms." I think that was a different view for them, because I think mostly in biology, and especially now in [redacted] with our Keystone Exam, we don't talk about animals, when we do it's simply the dissection, but this lab I enjoyed because they were alive, and then we used them for what we needed to, and then we were simply able to release them back into the environment."

In addition to interactions with living insects, some teachers pointed out the importance in explicitly introducing students to ethical research practices and had a plan for humane disposal.

> "We do talk about humane treatment as well. They're not allowed to squish the flies obviously, and when they do accidentally squish one, they usually feel really bad, so we do talk about humane treatment even though they're just flies, you have to treat them in a humane way. At the end, we're not supposed to let them go because we're in California. I have let them go though, just because I don't want them to ... We have a fly morgue too which is obviously a bottle of alcohol."

Enjoying teaching. In several cases, teachers' positive emotional connection to insects themselves or the process of teaching with insects was an important outcome of entomology incorporation. In most cases, teacher excitement for insects was evidenced by studying entomology either during a graduate program or by studying the subject in their own free time. In all cases, teachers described an almost contagious excitement which "generates a lot for the students" and allows students to "pick up the excitement from me". A teacher noted that students viewed her enthusiasm for insects as "weird", but also that her excitement appeared to be transferred to the students.

“I know they have made comments to other teachers, "Oh my god, she gets so excited about bugs. She's just so weird." You know kind of thing. But I know they get into it because of that. You know, the fact that I had the education. That I had the Masters in it, I know a lot about it. And the kids see that too. When you are excited about something in the classroom and you have the knowledge, they get a little more excited too.”

RQ2: Why do teachers choose to incorporate entomology into secondary science instruction?

Quantitative Results

Barriers to incorporation. In the survey, teachers were asked to identify barriers that inhibited entomology incorporation in their science classrooms. Results indicated that a perceived lack of alignment with state or national science standards and lack of fit with a prescribed curriculum were the most common barriers (Figure 4.6). In addition to the categorical responses provided, 40 teachers wrote in barriers including lack of time, prohibitive cost, and lack of facilities, knowledge, or ability to care for insects as potential barriers. These responses are not provided in Figure 4.6 because these teacher-generated responses are presented within the teacher beliefs and attitudes results in the following subsection (Figure 4.7).

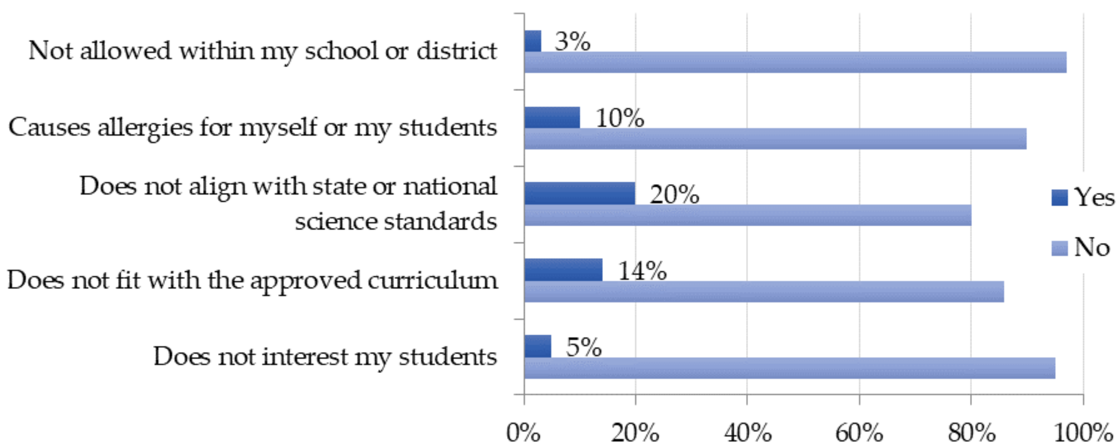

Figure 4.6. Barriers to incorporation

Teachers' beliefs and attitudes. Over three-quarters of teachers reported feeling comfortable handling insects (77%) and over half of teachers reported that the physical appearance of insects was appealing (60%). The most common concerns teachers reported were lack of time to teach about insects (43%), lack of adequate training (39%), and lack of availability of quality lesson plans (33%) (Figure 4.7). Surprisingly, despite 39% of teachers reporting a lack of adequate training, most teachers were confident in their ability to care for (64%) and teach about insects (67%).

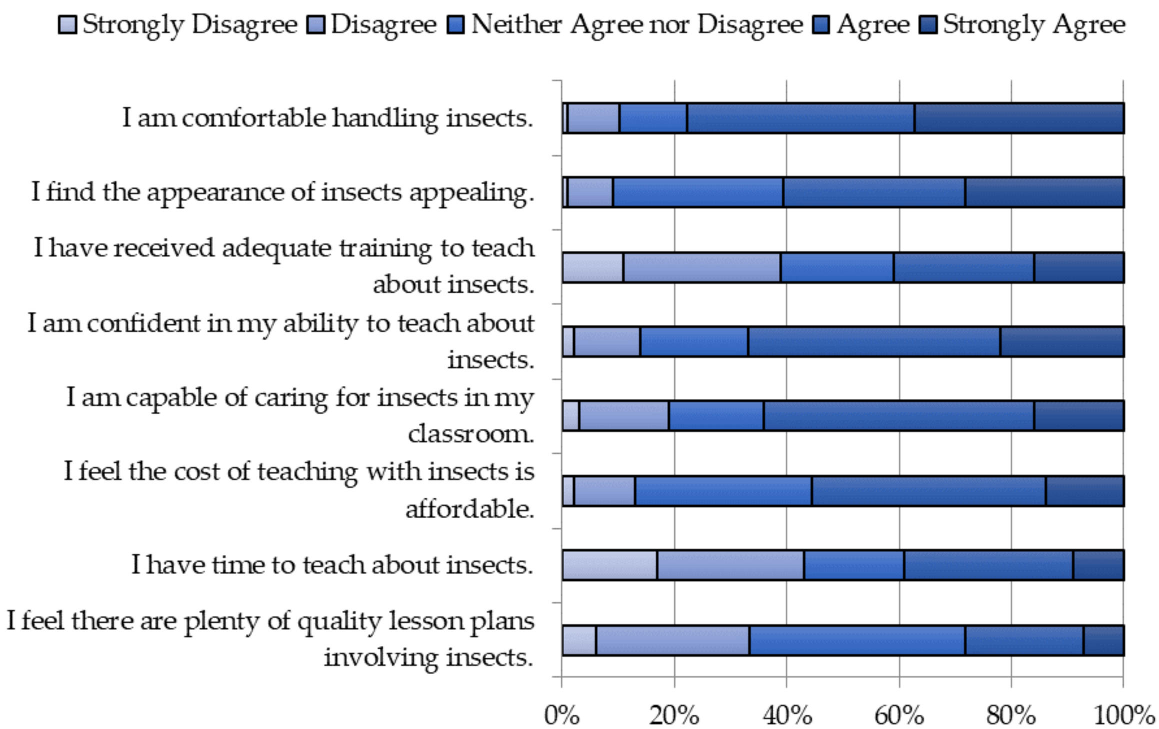

Figure 4.7. Teacher attitudes toward insects and entomology incorporation

Teachers' prior entomology experiences. Teachers were asked to report their formal or informal entomology experiences. Roughly one-third of teachers reported some sort of entomology experience in their background (Figure 4.8). While representing only 32% of responses (n=211), taking a college-level entomology course was the most common experience reported by 68 teachers. Sixty teachers reported attending a professional development workshop involving insects representing 29% of responses (n=208). Finally, 39 teachers reported having some other education experience with insects representing 39% of responses (n=100).

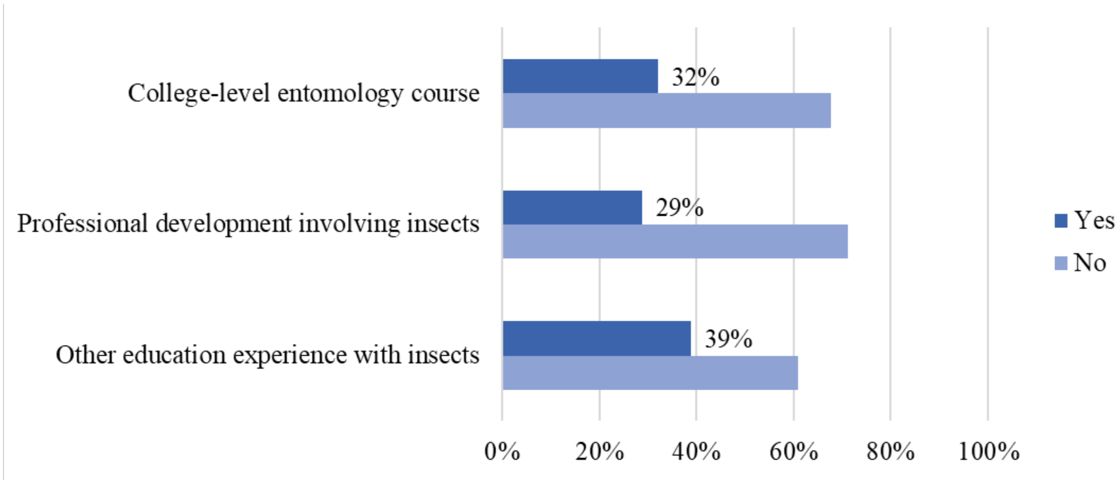

Figure 4.8. Teacher entomology education and experiences

Factors associated with different levels of entomological incorporation. Based on the results of the chi-square analyses, nearly all factors of interest (i.e. teachers' attitudes and beliefs, use of curriculum and instructional supports, and teachers' prior entomology experience) were associated with different levels of at least one aspect of entomology incorporation. Results for each of the factors of interest are discussed at greater length in the following sections.

Teachers' beliefs and attitudes. Cross tabulation analysis was conducted and chi-square statistics were calculated to test if a statistical relationship exists between eight different teacher attitudes or beliefs and different levels of entomology incorporation, measured across five aspects (Table 4.2). For each analysis, two variables were tested including each of the eight teacher attitudes or beliefs at three levels (disagree, neutral, and agree) and each aspect of incorporation at two levels (low and high). A summary of cross tabulation results is presented in Table 4.2.

Table 4.2. Results from chi-square analysis of cross tabulation for teacher beliefs and attitudes * level of entomology incorporation aspects.

		Aspect of Entomology Incorporation									
		Frequency	N	Insect Types Used	N	Entomology Topics	N	Science Concepts	N	Science Practices	N
Teacher Attitudes and Beliefs	Comfortable handling insects	χ^2=6.20 p=.045 V=.126	195	χ^2= 1.50 p=.473	192	χ^2=2.46 p=.293	195	χ^2=.35 p=.840	195	χ^2=9.61 p=.008 V=.223	193
	Find insect appearance appealing	χ^2=18.88 p=.000 V=.214	205	χ^2=16.08 p=.000 V=.289	192	χ^2=1.50 p=.472	195	χ^2=.13 p=.935	195	χ^2=.90 p=.638	193
	Received adequate training	χ^2=8.93 p=.012 V=.151	195	χ^2=15.59 p=.000 V=.285	191	χ^2=2.97 p=.226	194	χ^2=4.89 p=.087	194	χ^2=8.51 p=.014 V=.210	192
	Confident in teaching about insects	χ^2=7.64 p=.022 V=.140	194	χ^2=8.68 p=.013 V=.213	191	χ^2=.93 p=.629	194	χ^2=.81 p=.667	194	χ^2=9.48 p=.009 V=.222	192
	Capable of caring for insects	χ^2=5.92 p=.051	195	χ^2=3.21 p=.201	192	χ^2=2.53 p=.282	195	χ^2=1.23 p=.540	195	χ^2=4.33 p=.115	193
	Cost of insects affordable	χ^2=3.75 p=.153	195	χ^2=1.99 p=.371	192	χ^2=.16 p=.924	195	χ^2=.24 p=.886	195	χ^2=7.33 p=.026 V=.195	193
	Have time to teach about insects	χ^2=12.52 p=.002 V=.179	195	χ^2=4.45 p=.108	192	χ^2=3.90 p=.142	195	χ^2=1.28 p=.528	195	χ^2=16.74 p=.000 V=.294	193
	Plenty of quality lesson plans	χ^2=15.36 p=.000 V=.198	195	χ^2=5.02 p=.081	192	χ^2=6.39 p=.041 V=.181	195	χ^2=12.74 p=.002 V=.256	195	χ^2=4.64 p=.098	193

Shaded cells indicate significant differences at $p<0.05$ (light blue), $p<.01$ (medium blue), and $p<.001$ (dark blue). Cramer's V is denoted as V.

Frequency. Comfort handling insects and frequency of entomology incorporation were found to be significantly related, Pearson χ^2 (2, N = 195) = 6.20, p=.045. The proportion of teachers who reported a high frequency of incorporation (once a month or more) and who disagreed, felt neutral, or agreed that they felt comfortable handling insects was .04, .08, and .87, respectively (Figure 4.9). A teacher incorporating insects once a month or more was 21.75 times (.87/.04) more likely to report feeling comfortable handling insects to than feel uncomfortable.

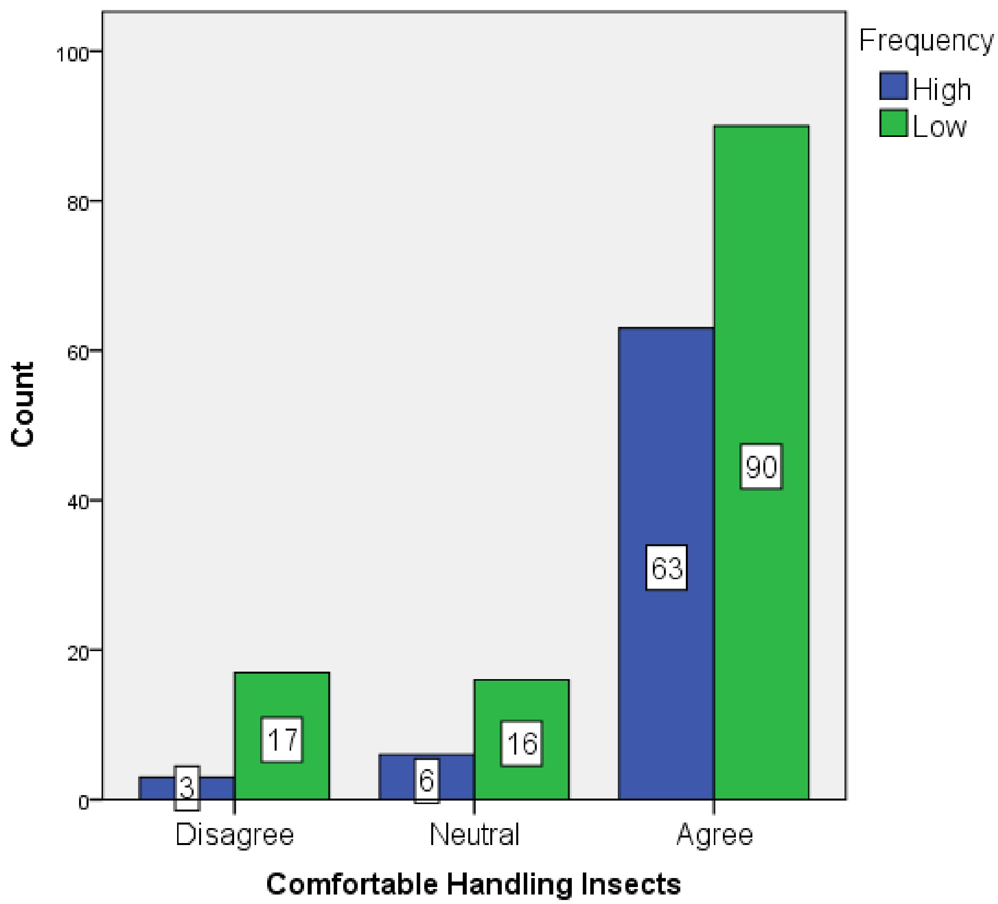

Figure 4.9. Clustered bar chart of teachers' frequency of incorporation across categories of comfort handling insects

Finding insect appearance appealing and entomology incorporation frequency were found to be significantly related, Pearson χ^2 (2, N = 205) = 18.88, p<.000. The proportion of teachers who reported a high frequency of incorporation (once a month or more) and who disagreed, felt neutral, or agreed that they found the appearance of insects to be appealing was .03, .18, and .79, respectively (Figure 4.10). A teacher incorporating insects once a month or more was 26.33 times (.79/.03) more likely to report finding insects appealing than unappealing.

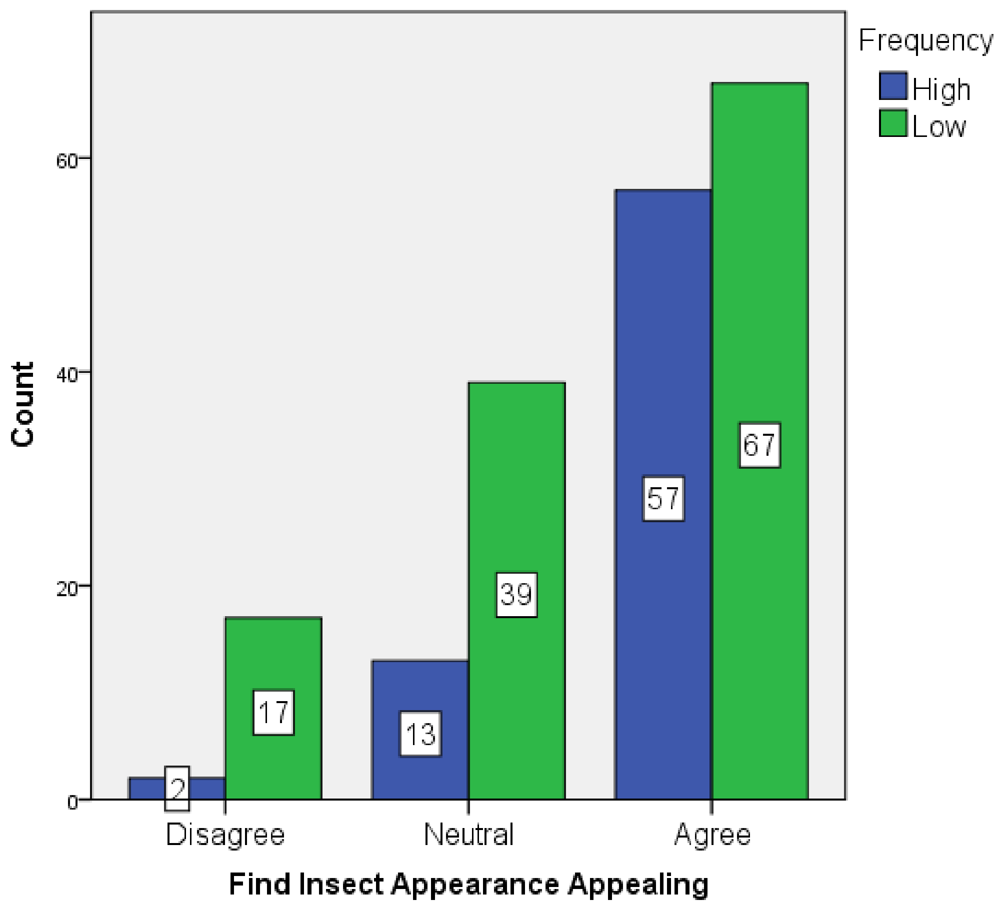

Figure 4.10. Clustered bar chart of teachers' frequency of incorporation across categories of attitude that insect appearance appealing

The belief that teachers had received adequate training to teach about insects and frequency of entomology incorporation were found to be significantly related, Pearson χ^2 (2, N = 195) = 8.93, p=.012. The proportion of teachers who reported a high frequency of incorporation (once a month or more) and who disagreed, felt neutral, or agreed that they had received adequate training to teach about insects was .24, .21, and .56, respectively (Figure 4.11). A teacher incorporating insects once a month or more was 2.33 times (.56/.24) more likely to report feeling that they had received adequate training to teach about insects than inadequate training.

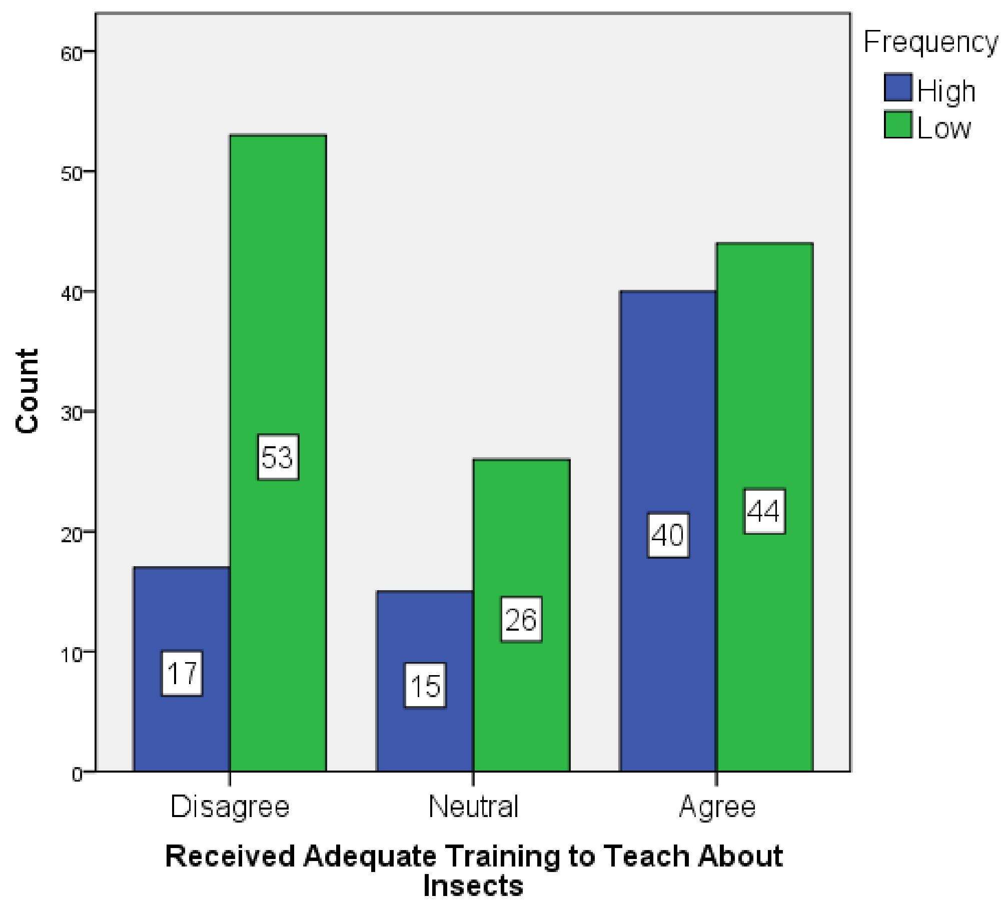

Figure 4.11. Clustered bar chart of teachers' frequency of incorporation across categories of belief in receiving adequate training to teach about insects

Teacher confidence in teaching about insects and entomology incorporation frequency were found to be significantly related, Pearson χ^2 (2, N = 194) = 7.64, p=.022. The proportion of teachers who reported a high frequency of incorporation (once a month or more) and who disagreed, felt neutral, or agreed that they felt confident in teaching about insects was .10, .15, and .79, respectively (Figure 4.12). A teacher incorporating insects once a month or more was 7.9 times (.79/.10) more likely to report feeling confident to teach about insects than not confident.

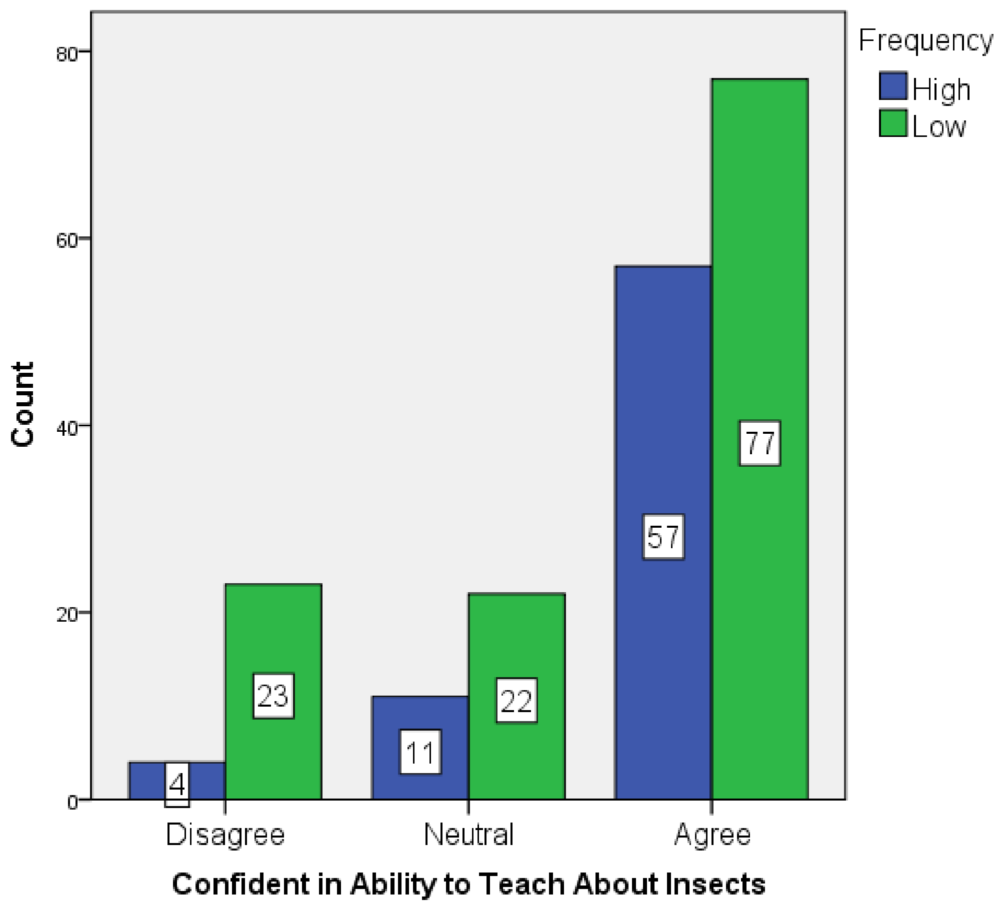

Figure 4.12. Clustered bar chart of teachers' frequency of incorporation across categories of confidence in ability to teach about insects

Teacher belief that adequate time was available to teach about insects and frequency of entomology incorporation were found to be significantly related, Pearson χ^2 (2, N = 195) = 12.52, p=.002. The proportion of teachers who reported a high frequency of incorporation (once a month or more) and who disagreed, felt neutral, or agreed that enough time was available to teach about insects was .24, .19, and .57, respectively (Figure 4.13). A teacher incorporating insects once a month or more was 2.38 times (.57/.24) more likely to report feeling that enough time was available to teach about insects than not enough time.

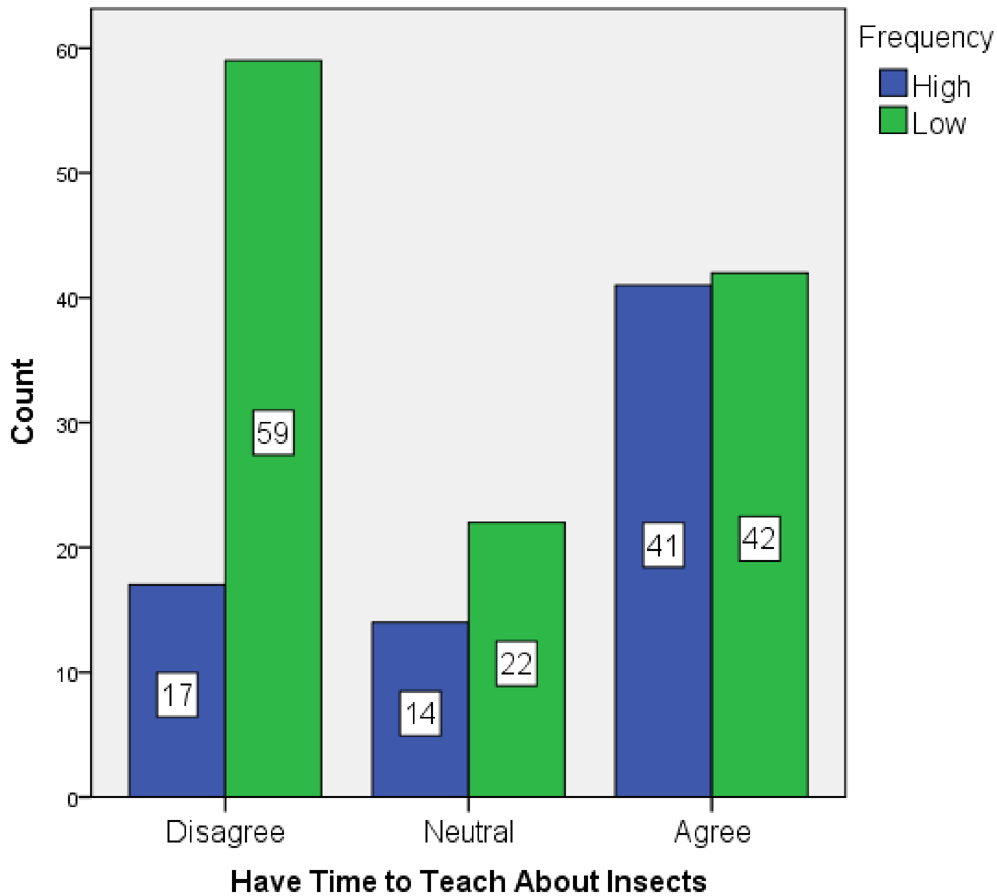

Figure 4.13. Clustered bar chart of teachers' frequency of incorporation across categories of belief that adequate time is available to teach about insects

Teacher belief that quality lesson plans were available and frequency of entomology incorporation were found to be significantly related, Pearson χ^2 (2, N = 195) = 15.36, p<.000. The proportion of teachers who reported a high frequency of incorporation (once a month or more) and who disagreed, felt neutral, or agreed that plenty of quality lesson plans were available to teach about insects was .19, .36, and .44, respectively (Figure 4.14). A teacher incorporating insects once a month or more was 2.31 times (.44/.19) more likely to report feeling plenty of quality lesson plans are available to teach about insects than not enough.

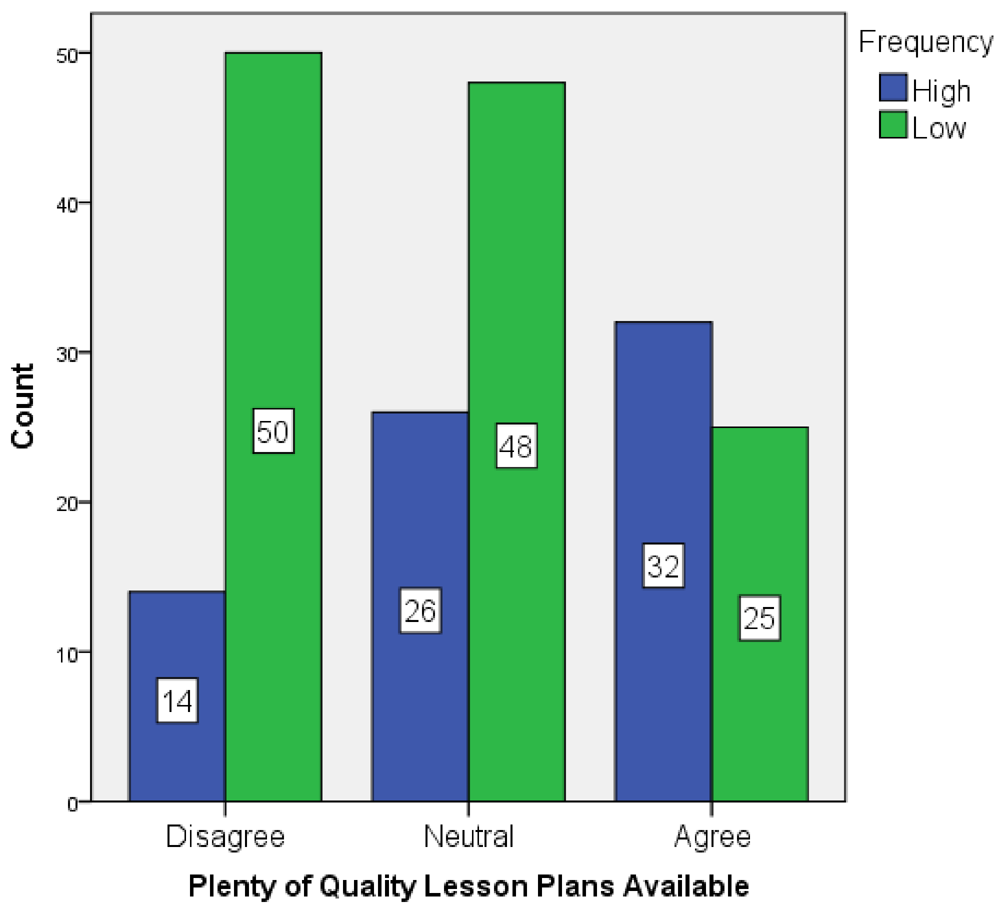

Figure 4.14. Clustered bar chart of teachers' frequency of incorporation across categories of belief that plenty of quality lesson plans are available

Diversity of insect types used. Finding insect appearance appealing and diversity of insects used were found to be significantly related, Pearson χ^2 (2, N = 205) = 16.08, p<.000. The proportion of teachers who reported a high diversity of insects used during incorporation (five or more insect types) and who disagreed, felt neutral, or agreed that they found the appearance of insects to be appealing was .04, .15, and .81, respectively (Figure 4.15). A teacher incorporating five or more insect types was 20.25 times (.81/.04) more likely to report finding insects appealing than unappealing.

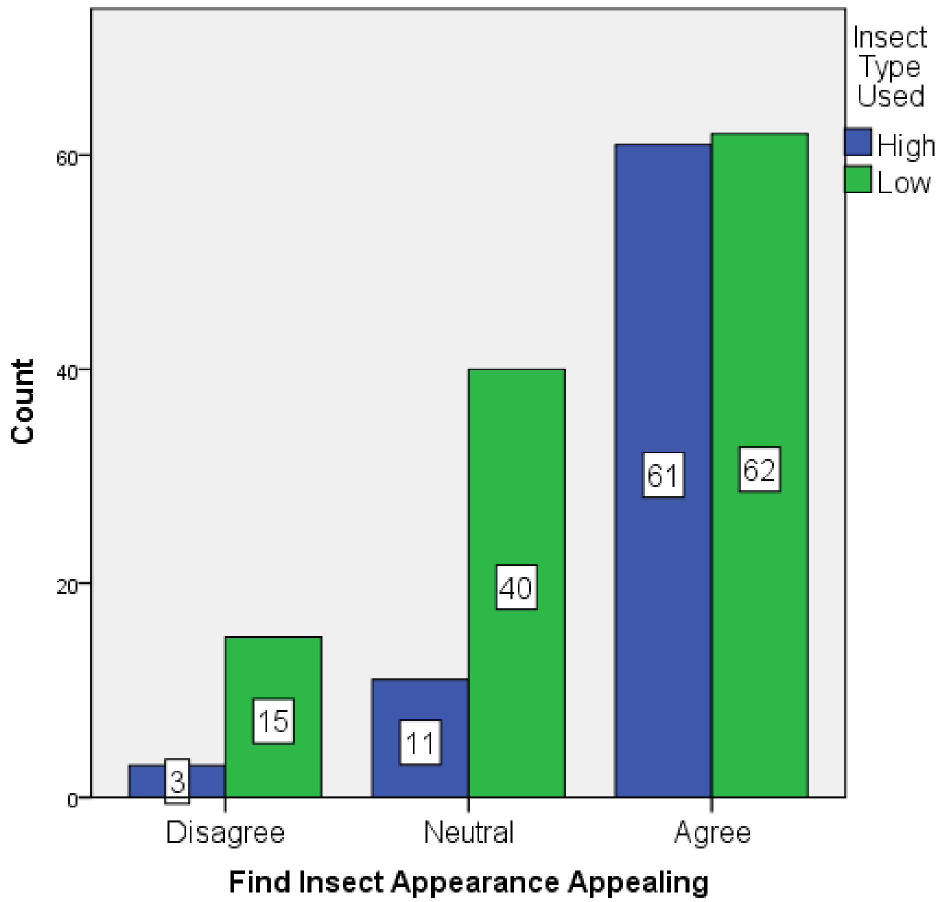

Figure 4.15. Clustered bar chart of teachers' diversity of insect types used across categories of attitude that insect appearance is appealing

The belief that teachers had received adequate training to teach about insects and diversity of insects used were found to be significantly related, Pearson χ^2 (2, N = 195) = 15.59, p<.000. The proportion of teachers who reported a high diversity of insects used during incorporation (five or more insect types) and who disagreed, felt neutral, or agreed that they had received adequate training to teach about insects was .21, .19, and .60, respectively (Figure 4.16). A teacher incorporating five or more insect types was 2.85 times (.60/.21) more likely to report feeling that they had received adequate training to teach about insects than inadequate training.

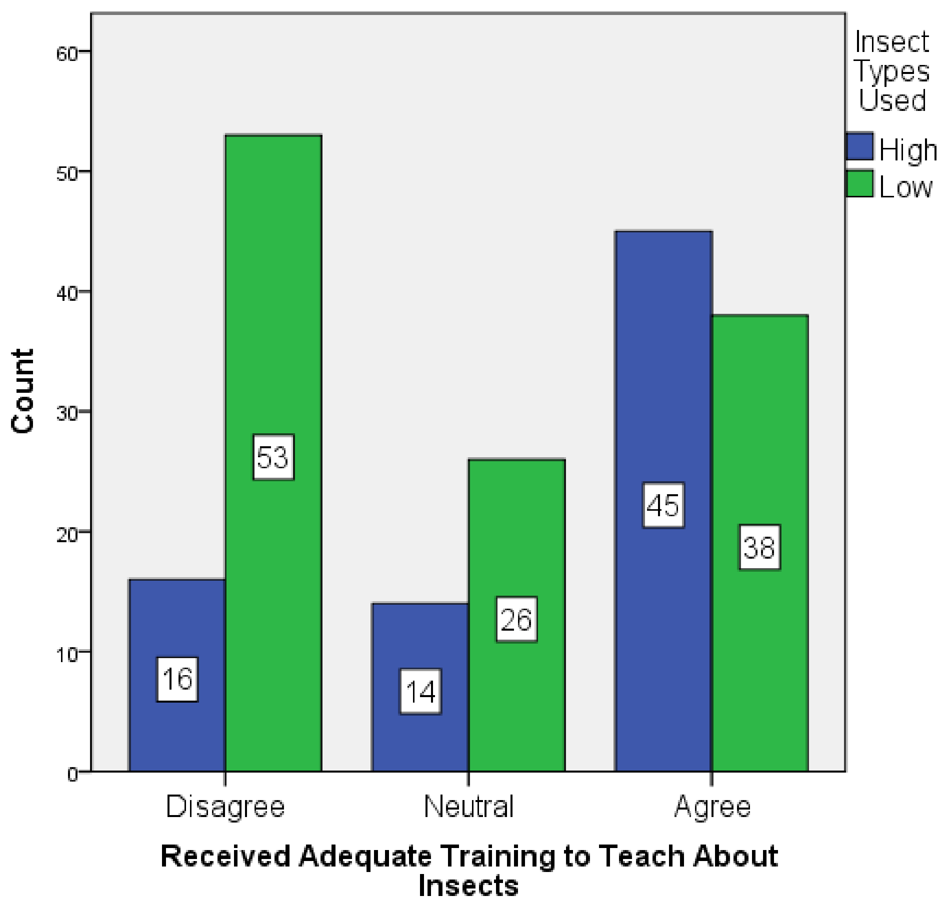

Figure 4.16. Clustered bar chart of teachers' diversity of insect types used across categories of belief in receiving adequate training to teach about insects

Teacher confidence in teaching about insects and diversity of insects used were found to be significantly related, Pearson χ^2 (2, N = 191) = 8.68, p=.013. The proportion of teachers who reported a high diversity of insects used during incorporation (five or more insect types) and who disagreed, felt neutral, or agreed that they felt confident in teaching about insects was .07, .12, and .81, respectively (Figure 4.17). A teacher incorporating five or more insect types was 11.57 times (.81/.07) more likely to report feeling confident to teach about insects than not confident.

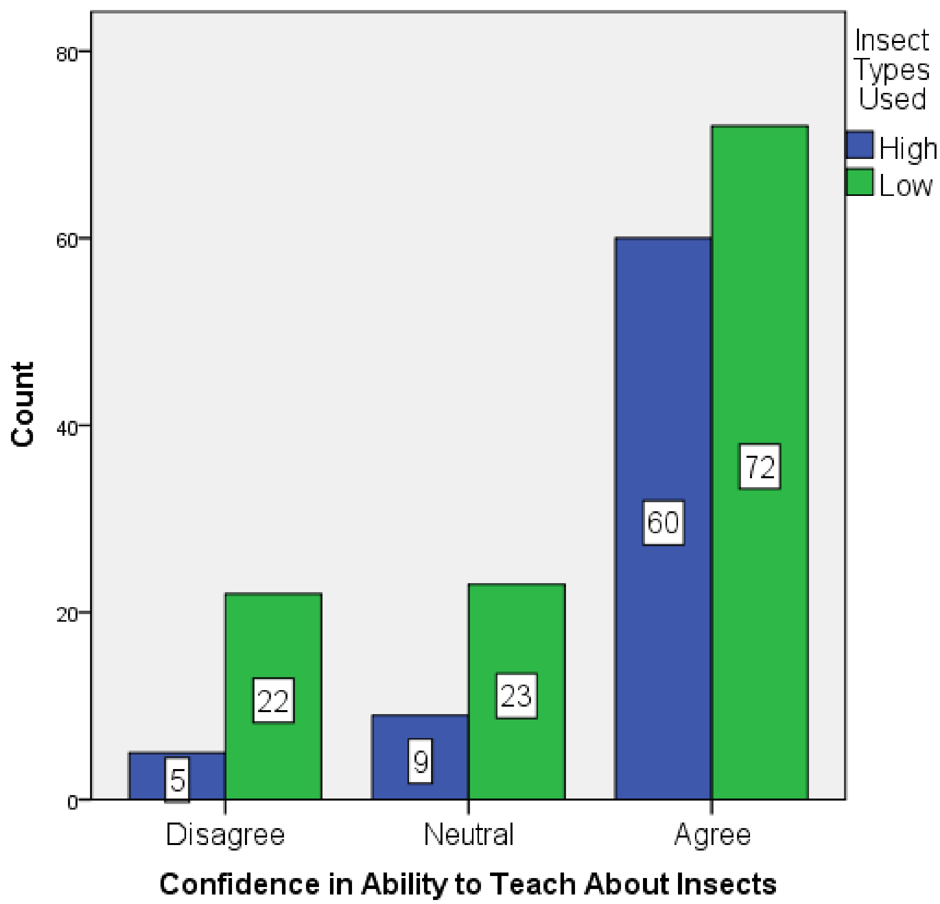

Figure 4.17. Clustered bar chart of teachers' diversity of insect types used across categories of confidence in ability to teach about insects

Entomology topics supported. Teacher belief that plenty of quality lesson plans were available and number of entomology topics supported by incorporation of entomology content were found to be significantly related, Pearson χ^2 (2, N = 195) =6.39, p=.041. The proportion of teachers who reported a low number of entomology topics supported by incorporation of entomology content (four or fewer topics) and who disagreed, felt neutral, or agreed that plenty of quality lesson plans were available to teach about insects was .41, .42, and .17, respectively (Figure 4.18). A teacher supporting four or fewer entomology topics through incorporation was 2.41 times (.41/.17) more likely to report disagreeing that plenty of quality lesson plans are available to teach about insects than agreeing.

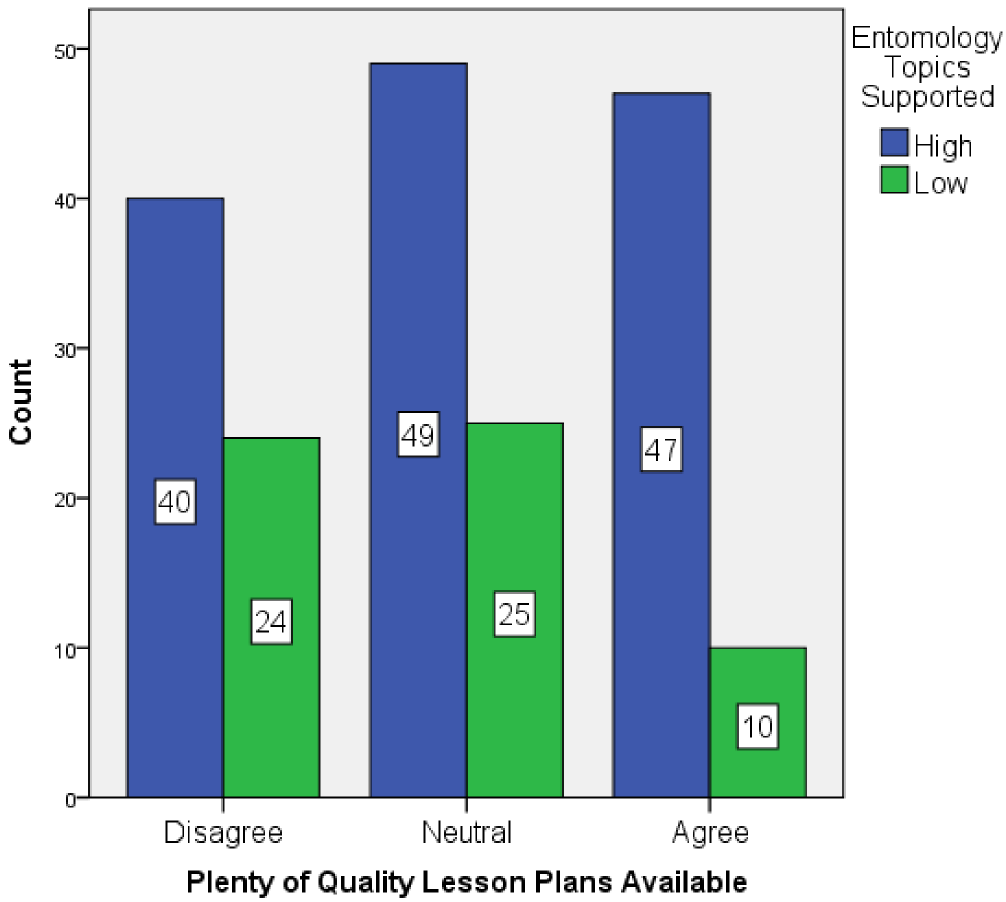

Figure 4.18. Clustered bar chart of number of entomology topics supported through incorporation of entomology content across categories of belief that plenty of quality lesson plans are available to teach about insects

Science concepts supported. Teacher belief that plenty of quality lesson plans were available and number of science concepts supported by incorporation of entomology content were found to be significantly related, Pearson χ^2 (2, N = 195) = 12.74, p=.002. The proportion of teachers who reported a low number of science concepts supported by incorporation of entomology content (four or fewer concepts) and who disagreed, felt neutral, or agreed that plenty of quality lesson plans were available to teach about insects was .48, .38, and .14, respectively (Figure 4.19). A teacher supporting four or fewer science concepts through incorporation was 3.43 times (.48/.14) more likely to report disagreeing that plenty of quality lesson plans are available to teach about insects than agreeing.

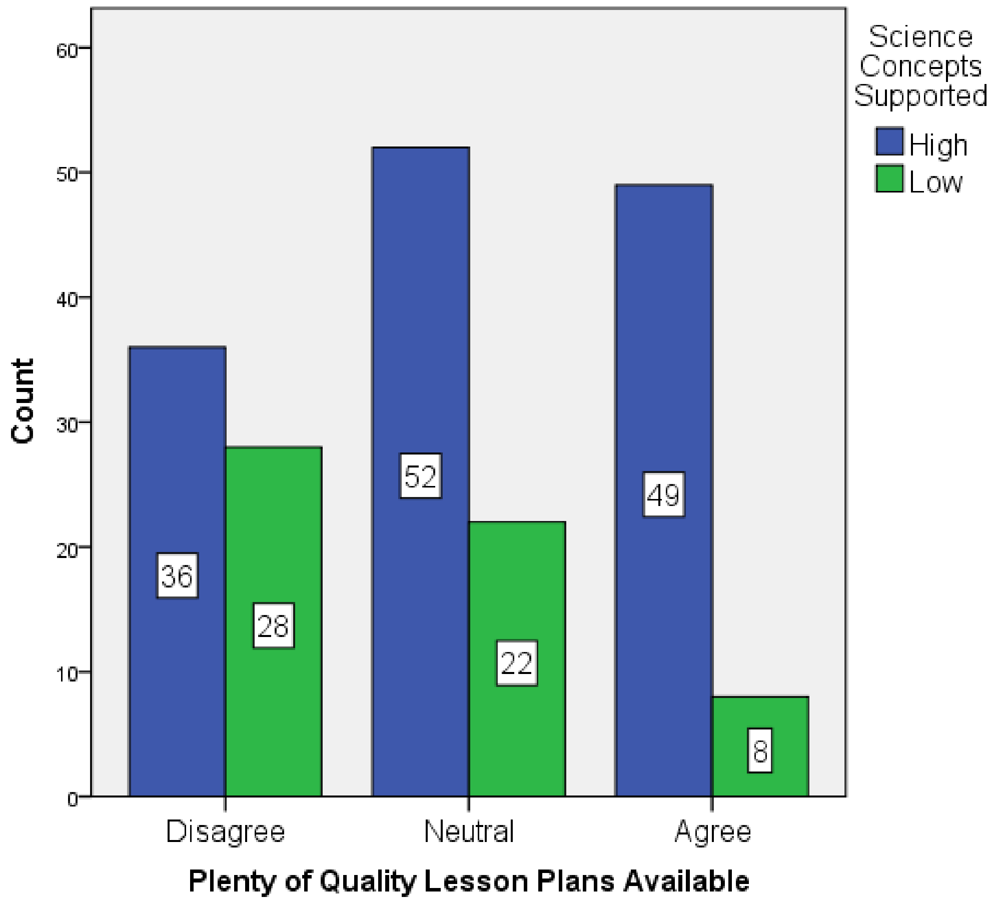

Figure 4.19. Clustered bar chart of number of science concepts supported through incorporation of entomology content across categories of belief that plenty of quality lesson plans are available to teach about insects

Science practices supported. Comfort handling insects and number of science practices supported by incorporation of entomology content were found to be significantly related, Pearson χ^2 (2, N = 193) = 9.61, p=.008. The proportion of teachers who reported a high frequency of incorporation (once a month or more) and who disagreed, felt neutral, or agreed that they felt comfortable handling insects was .08, .08, and .85, respectively (Figure 4.20). A teacher using entomology content to support five or more practices was 10.63 times (.85/.08) more likely to report feeling comfortable handling insects to than feel uncomfortable.

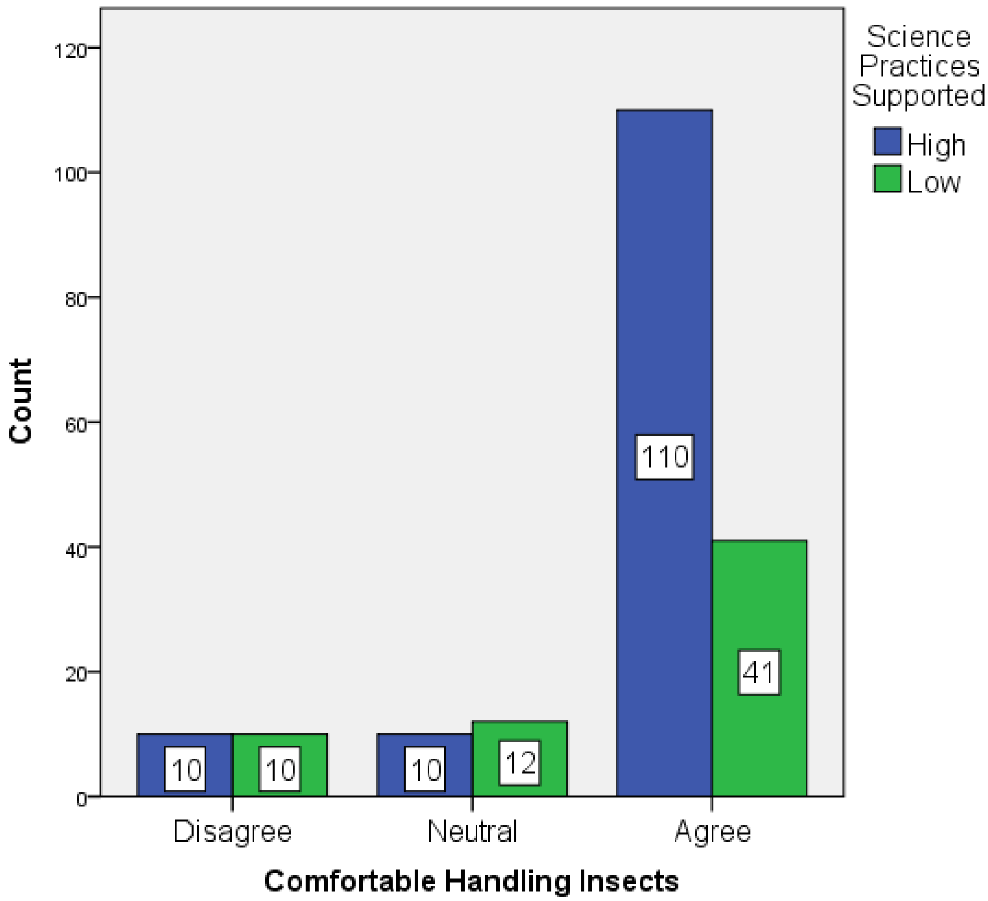

Figure 4.20. Clustered bar chart of number of science practices supported through incorporation of entomology content across categories of comfort handling insects

Teachers' belief that they had received adequate training to teach about insects and number of science practices supported by incorporation of entomology content were found to be significantly related, Pearson χ^2 (2, N = 192) = 8.51, p=.014. The proportion of teachers who reported a high frequency of incorporation (once a month or more) and who disagreed, felt neutral, or agreed that they had received adequate training to teach about insects was .30, .20, and .50, respectively (Figure 4.21). A teacher using entomology content to support five or more practices was 1.67 times (.50/.30) more likely to report feeling that they had received adequate training to teach about insects than inadequate training.

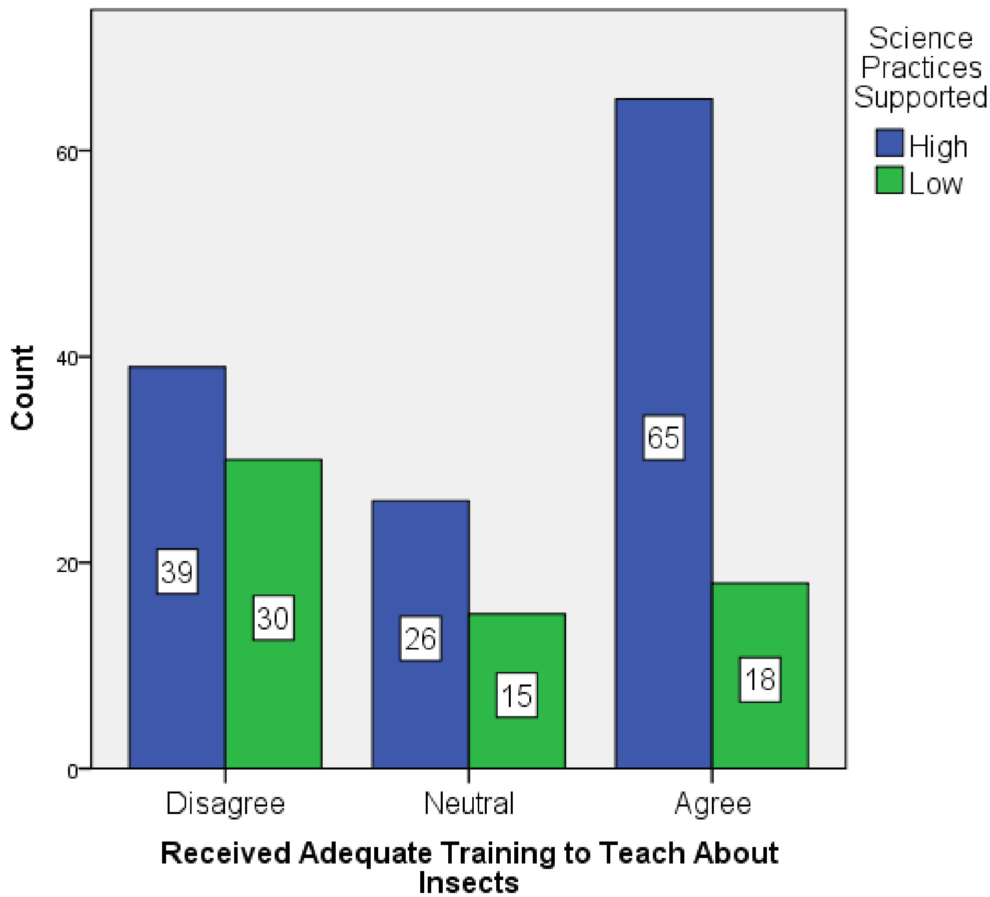

Figure 4.21. Clustered bar chart of number of science practices supported through incorporation of entomology content across categories of belief in receiving adequate training to teach about insects

Teacher confidence in teaching about insects and number of science practices supported by incorporation of entomology content were found to be significantly related, Pearson χ^2 (2, N = 192) = 9.48, p=.009. The proportion of teachers who reported a high frequency of incorporation (once a month or more) and who disagreed, felt neutral, or agreed that they felt confident in teaching about insects was .09, .16, and .75, respectively

(Figure 4.22). A teacher using entomology content to support five or more practices was 8.33 times (.75/.09) more likely to report feeling confident to teach about insects than not confident.

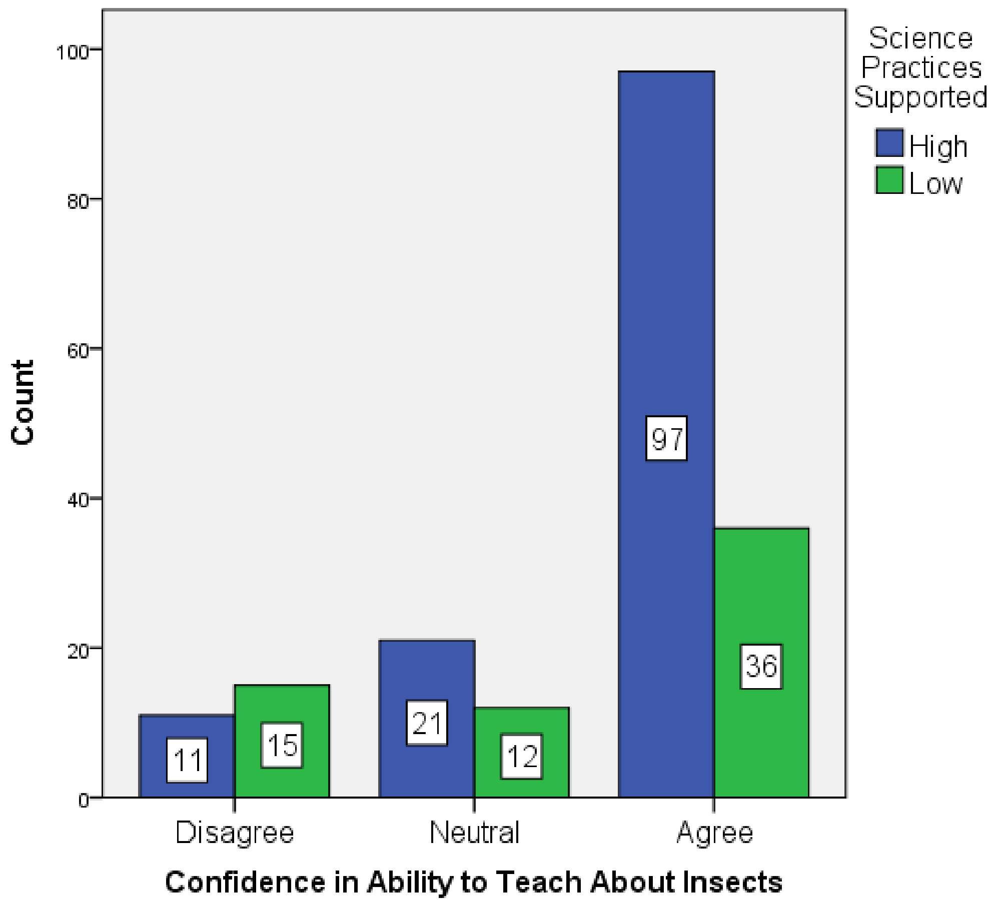

Figure 4.22. Clustered bar chart of number of science practices supported through incorporation of entomology content across categories of confidence in ability to teach about insects

Teachers' belief that the cost of insects is affordable and the number of science practices supported by incorporation of entomology content were found to be significantly related, Pearson χ^2 (2, N = 193) = 7.33, p=.026. The proportion of teachers who reported a high number of science practices supported by incorporation of entomology content (five or more practices) and who disagreed, felt neutral, or agreed that the cost of insects is affordable was .10, .26, and .64, respectively (Figure 4.23). A teacher using entomology content to support five or more practices was 6.4 times (.64/.10) more likely to report that the cost of insects is affordable than not affordable.

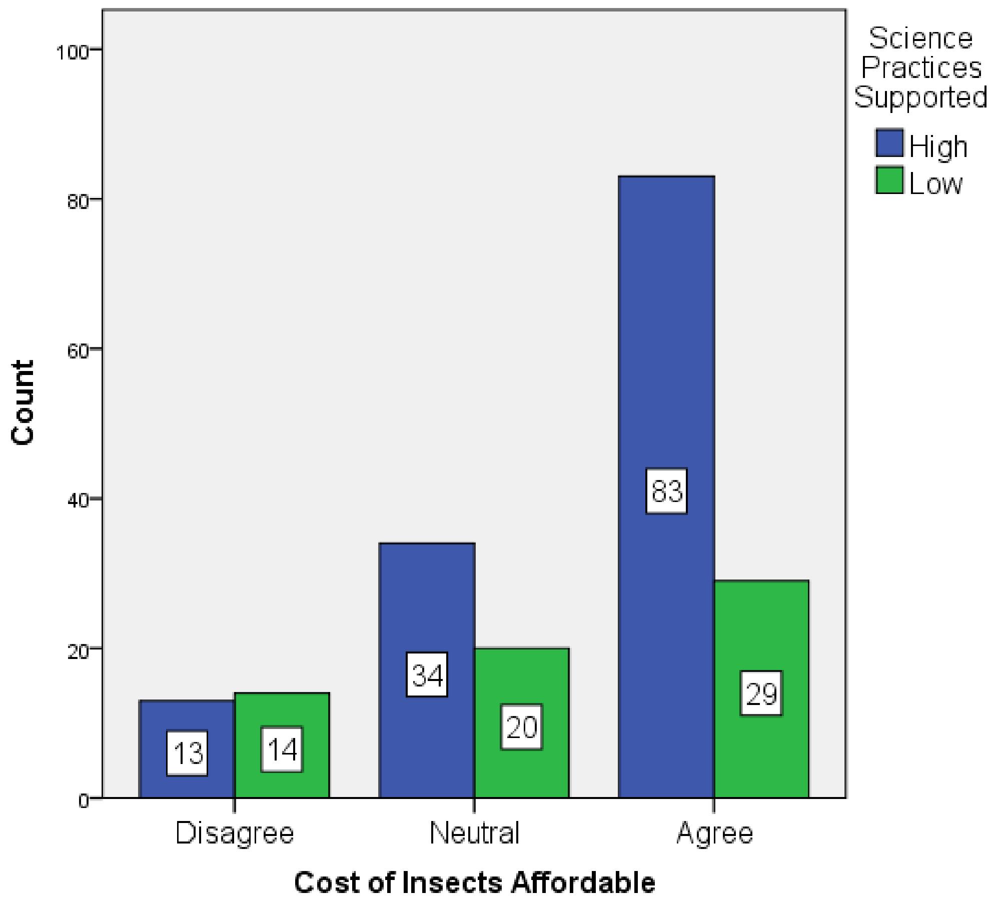

Figure 4.23. Clustered bar chart of number of science practices supported through incorporation of entomology content across categories of belief that the cost of insects is affordable

Teacher belief that adequate time was available to teach about insects and number of science practices supported by incorporation of entomology content were found to be significantly related, Pearson χ^2 (2, N = 193) = 16.74, p<.000. The proportion of teachers who reported a high number of science practices supported by incorporation of entomology content (five or more practices) and who disagreed, felt neutral, or agreed that enough time was available to teach about insects was .32, .15, and .53, respectively (Figure 4.24). A teacher using entomology content to support five or more practices was 1.65 times (.53/.32) more likely to report feeling that enough time was available to teach about insects than not enough time. In addition, the proportion of teachers who reported a low number of science practices supported by incorporation of entomology content (four or fewer practices) and who disagreed, felt neutral, or agreed that enough time was available to teach about insects was .55, .22, and .22, respectively (Figure 4.24). A teacher using entomology content to support five or more practices was 2.5 times (.55/.22) more likely to report feeling that not enough time was available to teach about insects than enough time.

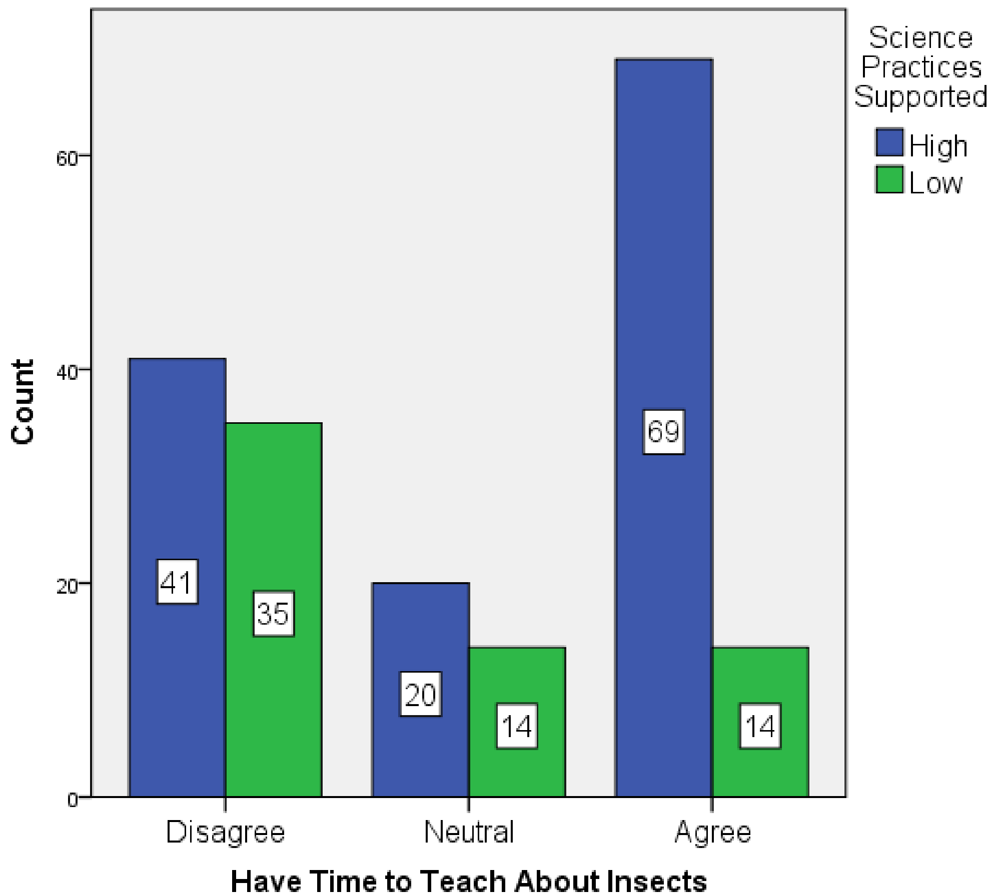

Figure 4.24. Clustered bar chart of number of science practices supported through incorporation of entomology content across categories of belief that adequate time is available to teach about insects

Use of curriculum and instructional supports. Cross tabulation analysis was conducted and chi-square statistics were calculated to test if a statistical relationship exists between three different uses of curriculum and instruction supports and different levels of entomology incorporation, measured across five aspects (Table 4.3). For each analysis, two variables were tested including each of the three curriculum and instructional supports at two levels (yes and no) and each aspect of incorporation at two levels (low and high). A summary of cross tabulation results is presented in Table 4.3

Table 4.3. Results from chi-square analysis of cross tabulation for use of curriculum and instruction supports * level of entomology incorporation aspects.

		Aspect of Entomology Incorporation									
		Frequency	N	Insect Types Used	N	Entomology Topics	N	Science Concepts	N	Science Practices	N
Use of Curriculum and Instruction Supports	Use of lesson plan	χ^2=.66 p=.416	211	χ^2=1.48 p=.224	205	χ^2=18.49 p=.000 Cramer's V=.299	207	χ^2=3.83 p=.050 Cramer's V=.136	206	χ^2=24.00 p=.000 Cramer's V=.348	198
	Use of self-created lesson plan	χ^2=1.90 p=.169	148	χ^2=5.49 p=.019 Cramer's V=.193	147	χ^2=.05 p=.817	146	χ^2=3.34 p=.067	145	χ^2=.07 p=.793	139
	Use of live insects	χ^2=1.11 p=.293	123	χ^2=.02 p=.901	122	χ^2=.10 p=.752	123	χ^2=.62 p=.433	123	χ^2=6.80 p=.009 Cramer's V=.236	122

Shaded cells indicate significant differences at p<0.05 (light blue), p<.01 (medium blue), and p<.001 (dark blue).

Diversity of insect types used. Use of a self-created lesson plan and diversity of insects used were found to be significantly related, Pearson χ^2 (1, N = 147) = 5.49, p=.019. The proportion of teachers who reported a high diversity of insects used during incorporation (five or more insect types) and who used or did not use a self-created lesson plan was .81 and .19, respectively (Figure 4.25). A teacher incorporating five or more insect types was 4.26 times (.81/.19) more likely to use a self-created lesson plan than not use one.

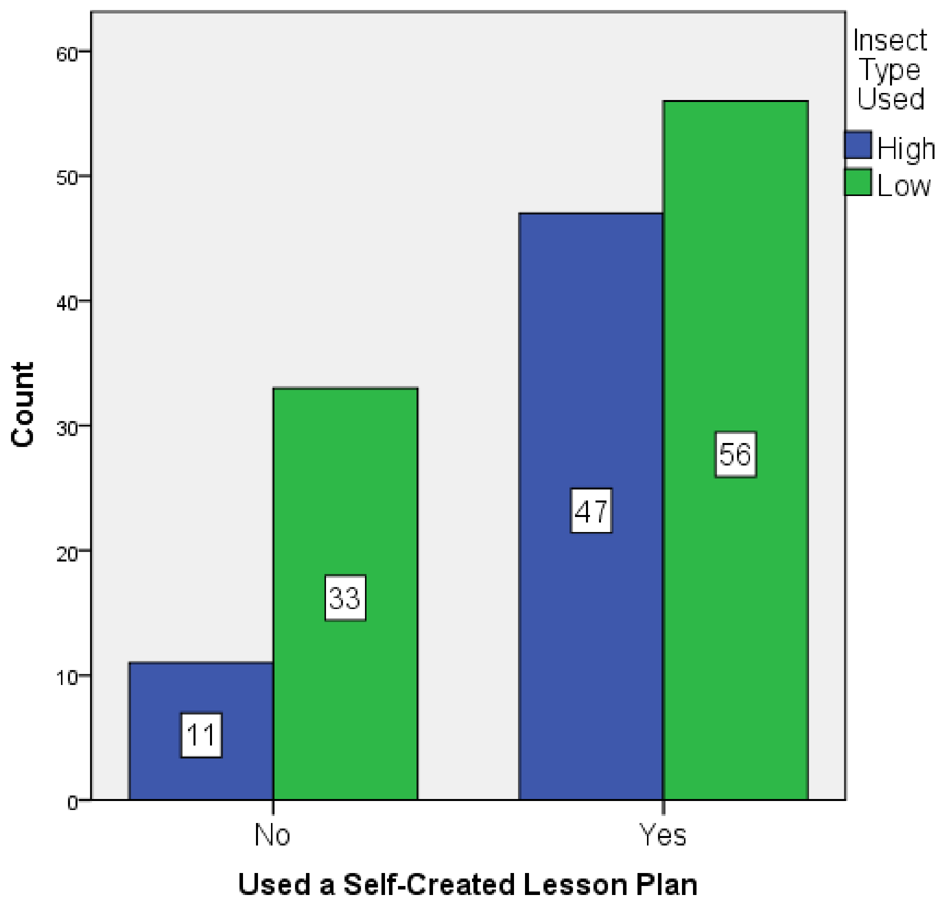

Figure 4.25. Clustered bar chart of teachers' diversity of insect types used across categories of self-created lesson plan use

Entomology topics supported. Use of a lesson plan and number of entomology topics supported by incorporation of entomology content were found to be significantly related, Pearson χ^2 (1, N = 207) = 18.49, p<.000. The proportion of teachers who reported a high number of entomology topics supported by incorporation of entomology content (five or more topics) and who used or did not use a lesson plan was .89 and .11, respectively (Figure 4.26). A teacher supporting five or more entomology topics was 8.09 times (.89/.11) more likely to use a lesson plan than not use one.

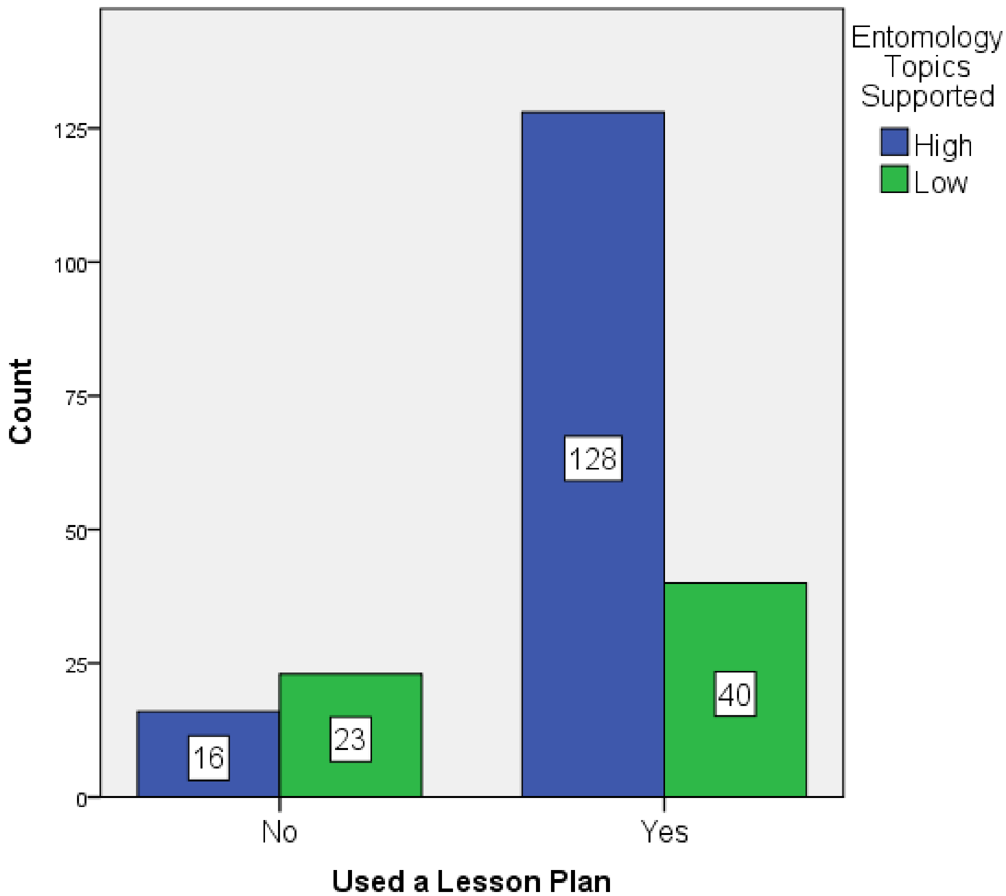

Figure 4.26. Clustered bar chart of number of entomology topics supported through incorporation of entomology content across categories of lesson plan use

Science concepts supported. Use of a lesson plan and number of science concepts supported by incorporation of entomology content were found to be significantly related, Pearson χ^2 (1, N = 206) = 3.83, p=.05. The proportion of teachers who reported supporting five or more science concepts and who used or did not use a lesson plan was .85 and.15, respectively (Figure 4.27). A teacher supporting five or more science concepts was 5.66 times (.85/.15) more likely to use a lesson plan than not use one.

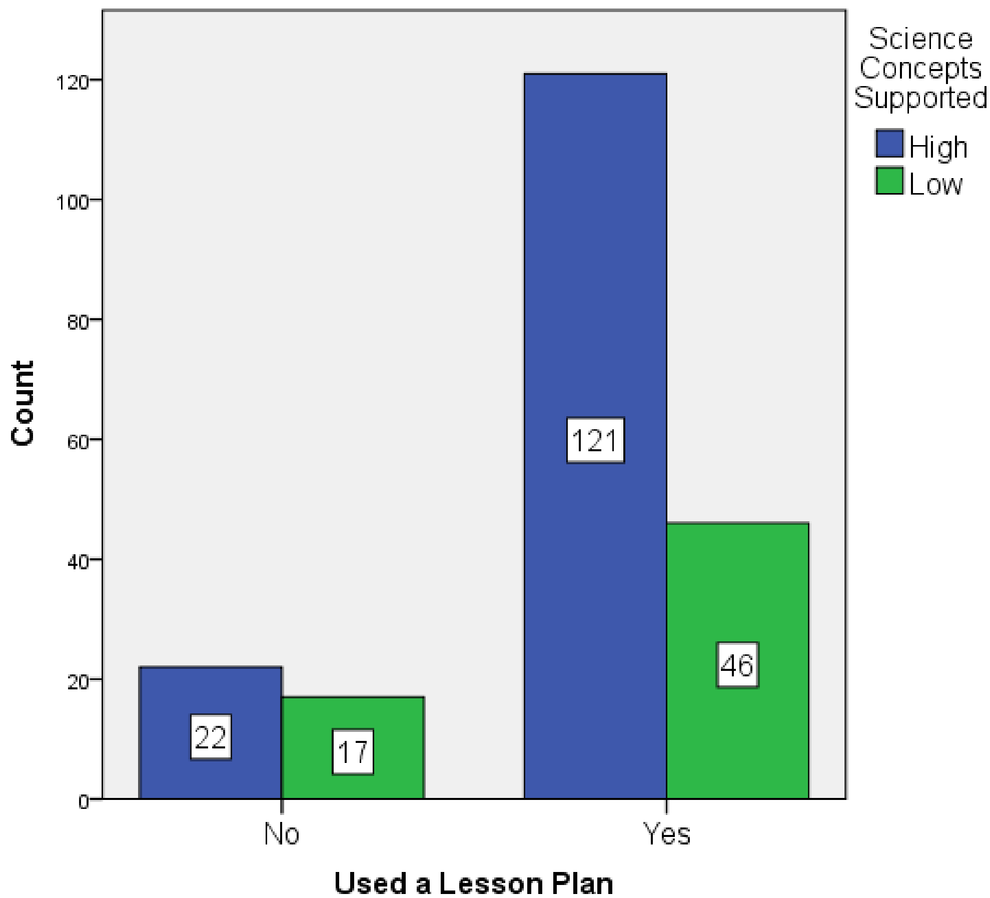

Figure 4.27. Clustered bar chart of number of science concepts supported through incorporation of entomology content across categories of lesson plan use

Science practices supported. Use of a lesson plan and number of science practices supported by incorporation of entomology content were found to be significantly related, Pearson χ^2 (1, N = 198) = 24.00, p<.000. The proportion of teachers who reported supporting five or more science practices and who used or did not use a lesson plan was .91 and .09, respectively (Figure 4.28). A teacher supporting five or more science practices was 10.11 times (.91/.09) more likely to use a lesson plan than not use one.

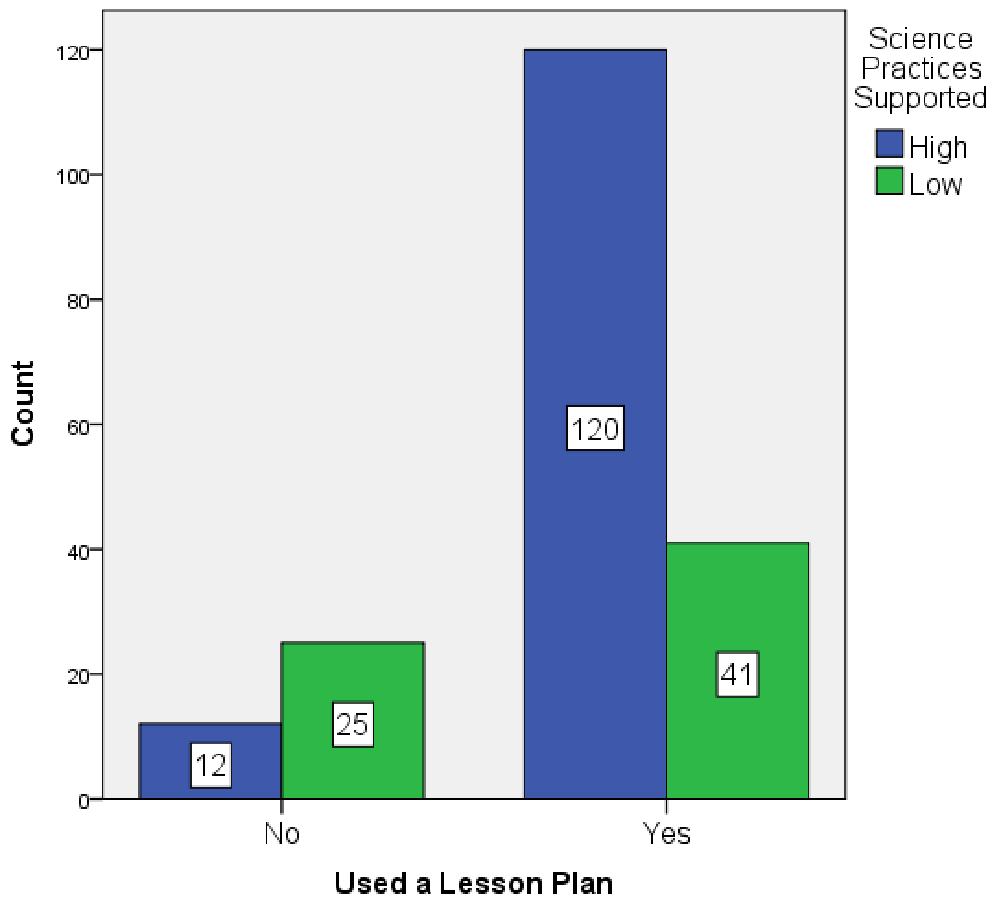

Figure 4.28. Clustered bar chart of number of science practices supported through incorporation of entomology content across categories of lesson plan use

Use of live insects and number of science practices supported by incorporation of entomology content were found to be significantly related, Pearson χ^2 (1, N = 122) =

24.00, p<.000. The proportion of teachers who reported supporting five or more science practices and who used or did not use live insects was .80 and .20, respectively (Figure 4.29). A teacher supporting five or more science practices was 4.0 times (.80/.20) more likely to use live insects than not use insects.

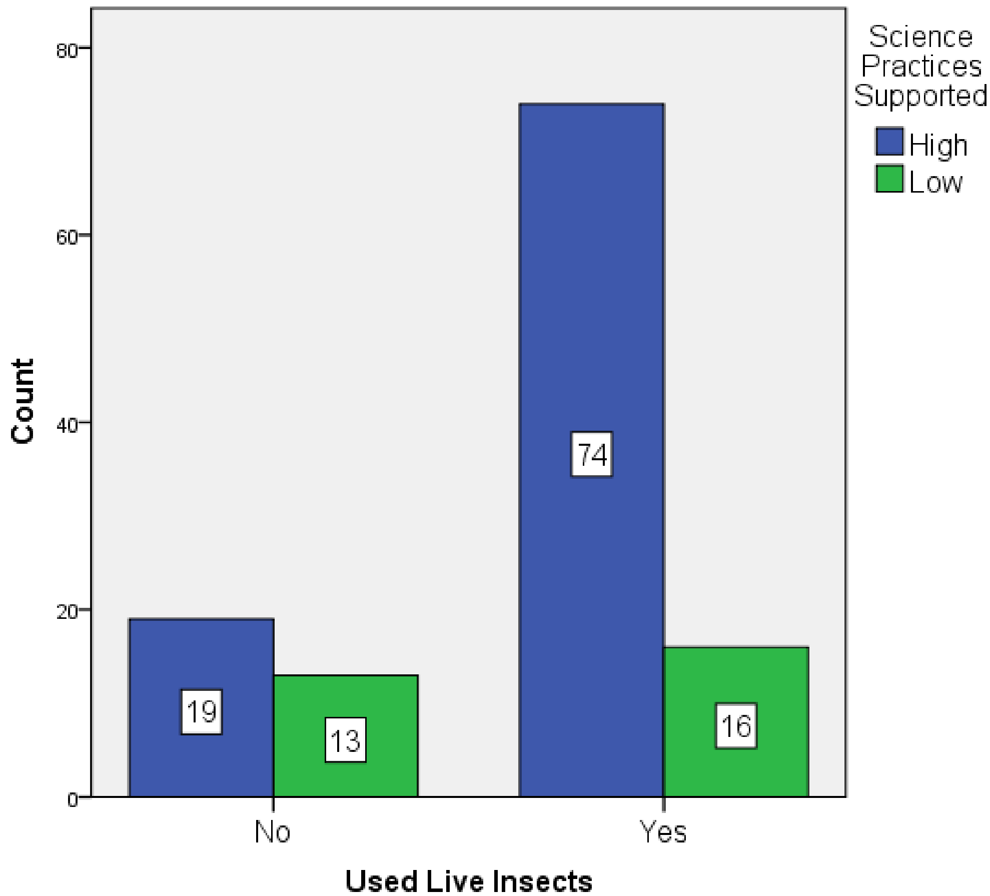

Figure 4.29. Clustered bar chart of number of science practices supported through incorporation of entomology content across categories of live insect use

Prior entomology experience. Cross tabulation analysis was conducted, and chi-square statistics were calculated to test if a statistical relationship exists between three different types of prior entomology experiences and different levels of entomology incorporation, measured across five aspects (Table 4.4). For each analysis, two variables were tested including each of the three prior types of entomology experience at two levels (yes and no) and each aspect of incorporation at two levels (low and high). A summary of cross tabulation results is presented in Table 4.4.

Table 4.4. Results from chi-square analysis of cross tabulation for teachers' prior entomology experience * level of entomology incorporation aspects.

		Aspect of Entomology Incorporation									
		Frequency	N	Insect Types Used	N	Entomology Topics	N	Science Concepts	N	Science Practices	N
Teachers' Prior Entomology Experience	College-level entomology course	$\chi^2=2.89$ p=.089	189	$\chi^2=10.20$ p=.001 Cramer's V=.234	186	$\chi^2=.01$ p=.911	189	$\chi^2=.45$ p=.501	189	$\chi^2=.01$ p=.941	187
	Professional development with insects	$\chi^2=5.39$ p=.020 Cramer's V=.170	187	$\chi^2=1.25$ p=.264	184	$\chi^2=.05$ p=.828	187	$\chi^2=2.77$ p=.096	187	$\chi^2=7.79$ p=.005 Cramer's V=.205	185
	Other entomology experience	$\chi^2=9.85$ p=.002 Cramer's V=.269	139	$\chi^2=5.13$ p=.024 Cramer's V=.196	133	$\chi^2=.05$ p=.826	136	$\chi^2=.06$ p=.802	136	$\chi^2=2.08$ p=.149	134

Shaded cells indicate significant differences at p<0.05 (light blue), p<.01 (medium blue), and p<.001 (dark blue).

Frequency. Teachers having participated in professional development training involving insects and frequency of entomology incorporation were found to be significantly related, Pearson χ^2 (1, N = 187) = 5.39, p=.020. The proportion of teachers who reported a low frequency of incorporation (less than once a month) and who had participated or not participated in a professional development involving insects was .24 and .76, respectively (Figure 4.30). A teacher incorporating four or fewer insect types was 3.16 times (.76/.24) more likely to not have participated in professional development training involving insects than to have participated.

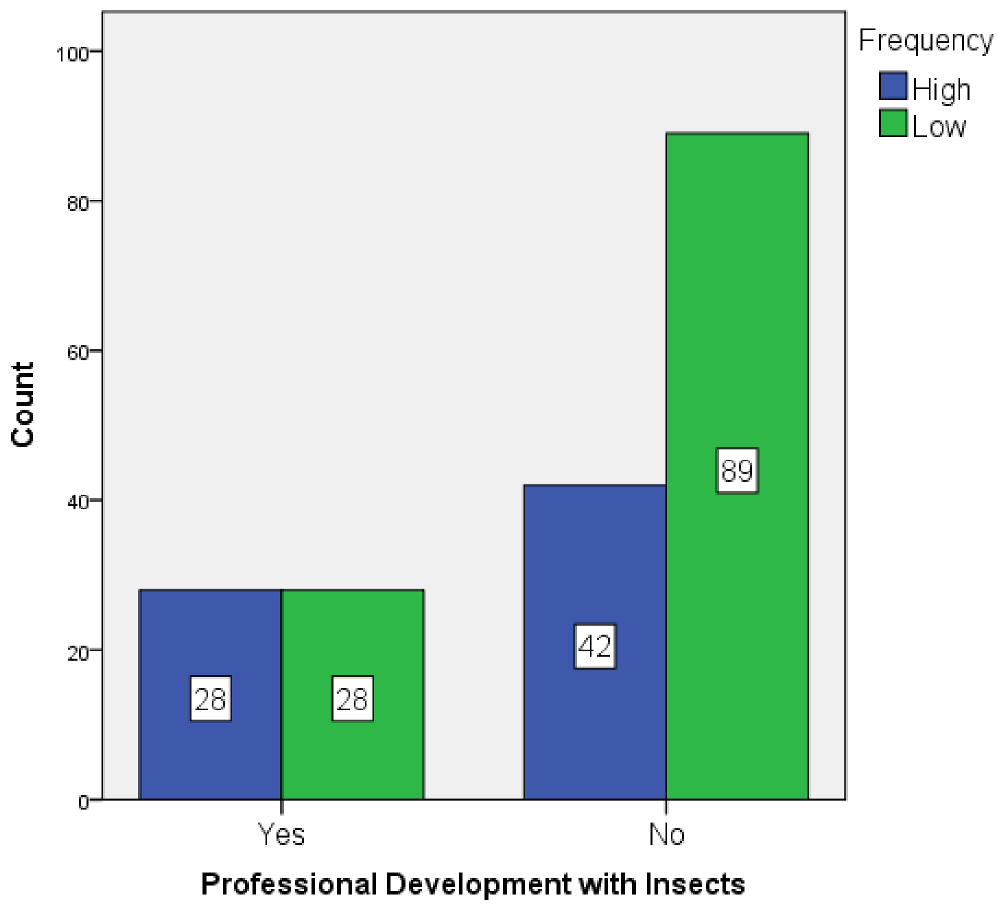

Figure 4.30. Clustered bar chart of frequency across categories of prior professional development experience with insects

Teachers having had other entomology experiences involving insects and entomology incorporation frequency were found to be significantly related, Pearson χ^2 (1, N = 136) = 9.85, p=.002. The proportion of teachers who reported a low frequency of incorporation (less than once a month) and who had participated or not participated in other entomology experiences was .20 and .80, respectively (Figure 4.31). A teacher incorporating entomology less than once a month was 4.0 times (.80/.20) more likely to not have participated than to have participated in other entomology experiences.

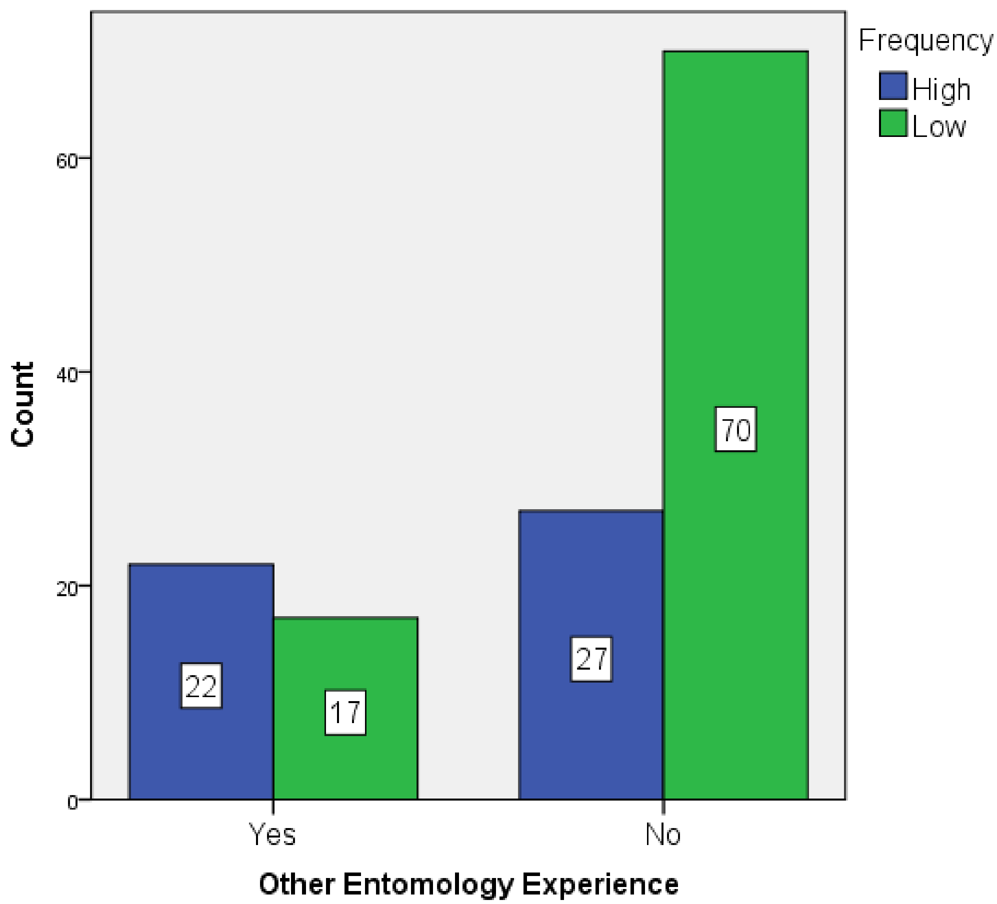

Figure 4.31. Clustered bar chart of frequency across categories of other prior entomology experience

Diversity of insect types used. Teachers having taken a college-level entomology course and level of diversity of insects used were found to be significantly related, Pearson χ^2 (1, N = 186) = 10.20, p=.001. The proportion of teachers who reported a low diversity of insects used during incorporation (four or fewer insect types) and who had taken or had not taken a college-level entomology course was .25 and .75, respectively (Figure 4.32). A teacher incorporating four or fewer insect types was 3.0 times (.75/.25) more likely to not have taken a college-level entomology course than to have taken a college-level entomology course.

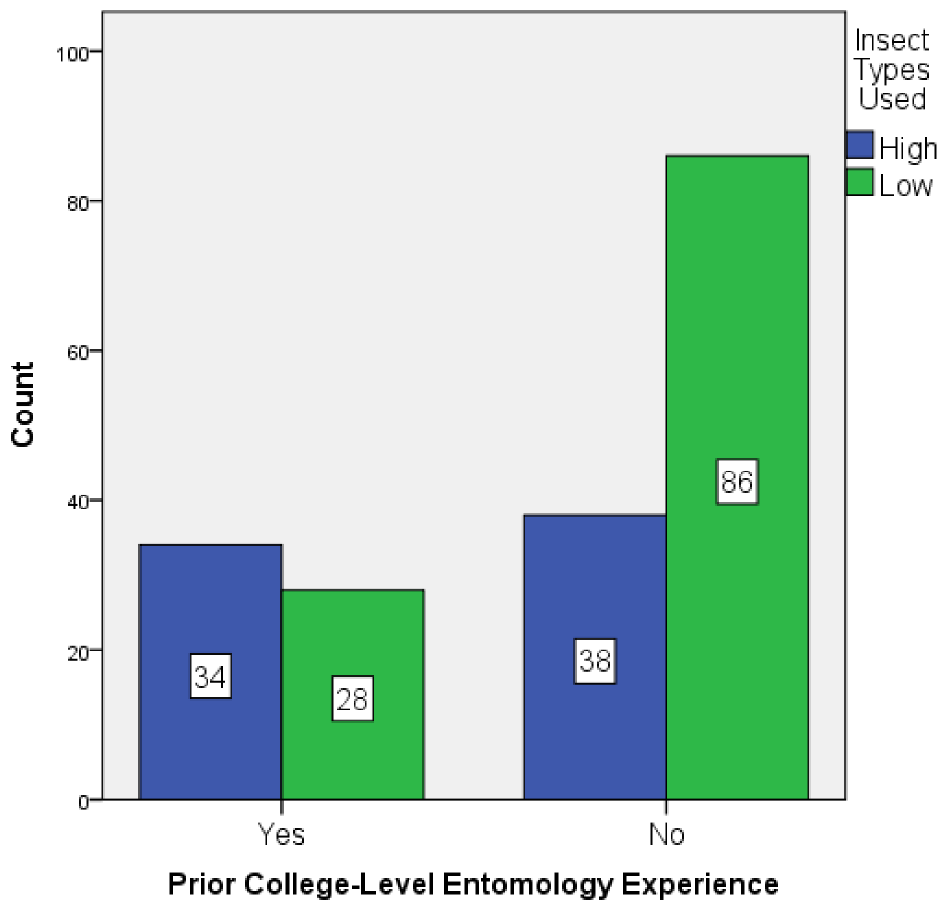

Figure 4.32. Clustered bar chart of teachers' diversity of insect types used across categories of prior college-level entomology course experience

Teachers having participated in other entomology experiences and level of diversity of insects used were found to be significantly related, Pearson χ^2 (1, N = 133) = 5.13, p=.024. The proportion of teachers who reported a low diversity of insects used during incorporation (four or fewer insect types) and who had or did not have other entomology experience was .22 and .78, respectively (Figure 4.32). A teacher incorporating four or fewer insect types was 3.55 times (.78/.22) more likely to not had other entomology experience than to have had such experience.

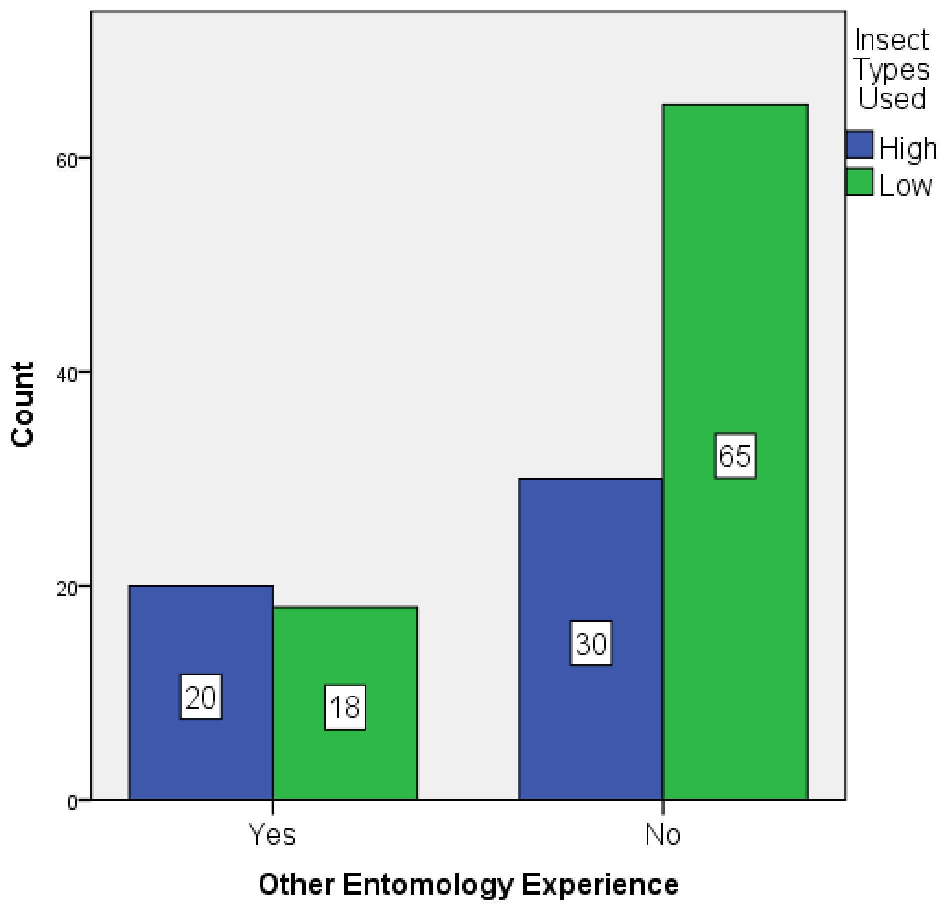

Figure 4.33. Clustered bar chart of teachers' diversity of insect types used across categories of other prior entomology experience

Science practices supported. Teachers having participated in professional development training involving insects and number of science practices supported through incorporation of entomology content were found to be significantly related, Pearson χ^2 (1, N = 185) = 7.79, p=.005. The proportion of teachers who had participated in a professional development involving insects and supported a low or high level of science practices using entomology content was .18 and .82, respectively (Figure 4.34). A teacher participating in professional development with insects was 4.55 (.82/.18) times more likely to support a high level rather than a low level of science practices when incorporating entomology content.

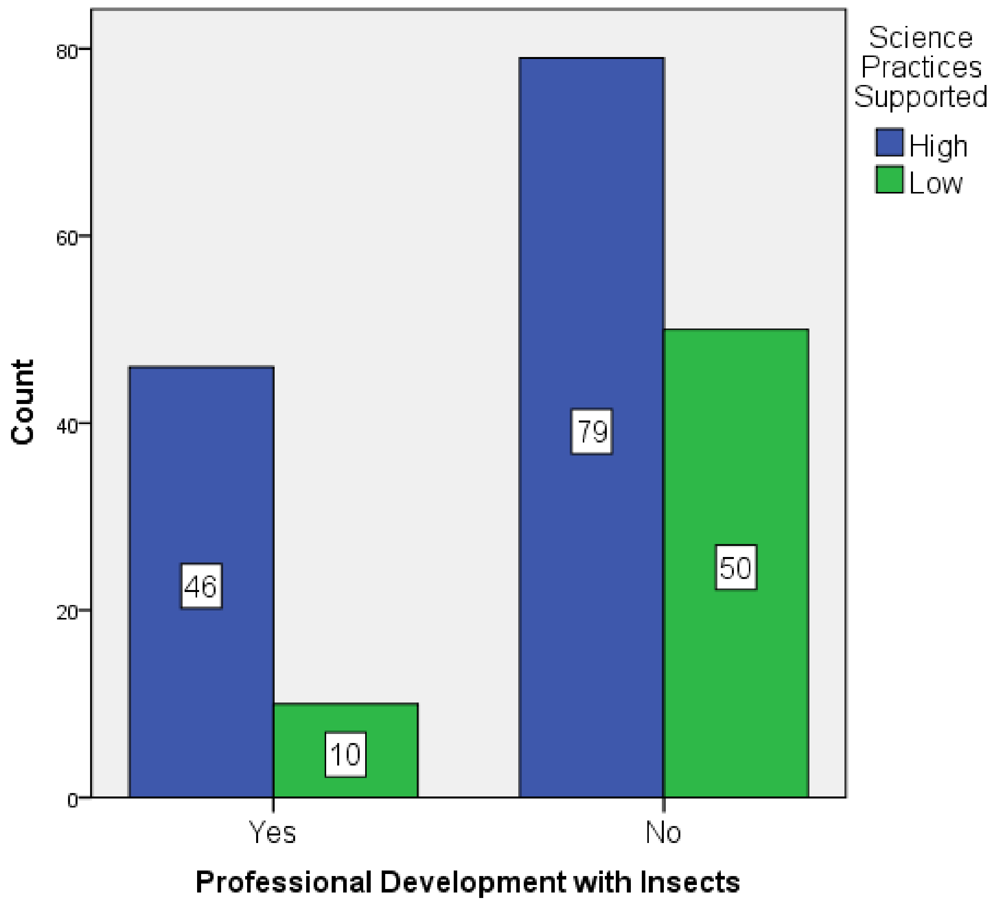

Figure 4.34. Clustered bar chart of number of science practices supported through incorporation of entomology content across categories of prior professional development experience with insects

Qualitative Findings

Facilitators and barriers. While quantitative results indicated factors of interest that were associated with higher levels of entomology incorporation, the qualitative interviews provided an opportunity to explore classroom realities that impact a teachers' ability to incorporate insects into science instruction. Findings from the teacher interviews provided a more complete understanding of the formal science classroom as a setting for entomology to be taught and factors that function as facilitators or barriers to entomology incorporation practices.

Access to necessary entomology resources. Teachers commonly discussed having access to entomology resources such as live insects, pinned or preserved specimens, and laboratory or collection equipment as a key facilitator to entomology incorporation. Teachers gained access to live insects for instruction in several ways. When weather was suitable for insect survival, teachers commonly mentioned collecting insects in the local area. Teachers explained that green spaces or outdoor areas "within walking distance of the school" facilitated "collecting" or "watching" insects during the school day. In one case, a teacher discussed how habitat suitability and school location impacted the effectiveness of insect collecting.

> "So, our school is in a different location than it used to be. Where we were in north [redacted, major U.S. city] before, there weren't really great locations to go and collect insects, because that's a requirement of the curriculum. Where we are now is right across from a park, and there's a small pond, so the diversity of insects is much larger, so it makes this project work much better."

Location was not the only factor teachers needed to consider when having students collect insects. Timing was also important. In some cases, teachers asked students to collect insects during the summer when school was not in session.

> “I usually start the students in the summer before they come in. I give them materials, pins and pinning blocks and that type of thing. I give them directions on how to make a box and a net. And those types of things. And a killing jar. So, I give them that stuff and I get them started in the summer time. And then when they come to class. That's where we do most of the pinning and the identification.”

Some teachers did not mention including students in the insect collecting process but described personally “catching something at home and bringing it in” and occasionally, live insects found within the school would be inserted into instruction through more spontaneous “teachable moments”. One teacher recounted an incident when a cockroach was captured and presented during a teaching evaluation.

> “I know when I had an observer in the room, this large cockroach came running across behind my desk and I stomped on it, dumped it in a petri dish, taped it shut and passed it around the room. You know it was there so we could look at it. She was like, "Wow, talk about, you know, in the moment, incorporating things into your lesson." But I kind of do those things automatically and the kids know that I'm going to be passing something around if it comes my way.”

Several teachers did not rely on collecting insects in the local area for experiments and instead, purchased live insects from “biological supply companies”, “pet stores”, or “bait shops" because it was "simple" and "easy". Teachers seemed to appreciate the dependability and ease of purchasing live insects rather than collect them.

In addition to live insects, several teachers discussed the importance of access to pinned or preserved specimens. Access to an insect collection provided an on-demand teaching tool that could be used when live insects were not available. Pinned specimens were used for a variety of purposes, but several teachers discussed their value in supporting student-driven learning. One teacher described how an insect collection could be used to spark students' curiosity rather than any predetermined learning outcome.

> "When I take the collection out and I put them out, I did a lot of impromptu questions and teachable moments, especially about their eyes, especially about dragonflies four wings and their unbelievable acrobatics in the air and stuff like that. And it's mostly, really, that I've become interested and read about them and then I am equipped to handle kids' questions that are coming right off the cuff. More so than any planned lesson that works out. Lessons are good, but the lessons are more like, um, they're not experiments, they're exercises. So, I know what's supposed to happen in the cell respiration lab where we manipulate the temperature of the mealworms. But I don't know what's going to be asked when I open this collection and I find that all the really good learning and all the real good interaction goes on when the kids are just... wondering."

Lastly, teachers discussed how access to the right "tools" or "equipment" such as dissecting microscopes, collecting nets, killing jars, pins, display boxes, and dichotomous keys would support student interactions with living insects or examination of pinned specimens. One teacher purchased laboratory equipment for measuring cellular respiration and discussed how this equipment worked well with insects as model organisms.

> "We bought some Probeware through Vernier and it enabled us to measure things like oxygen and carbon dioxide production down to like the parts per million. And when we did that our labs became a little more sophisticated. I was able to do a little more sophisticated labs and I found that the perfect, for example for our cell respiration lab, the perfect critter was mealworms."

Insect characteristics. The suitability of live insects for scientific experiments or investigations was commonly mentioned as facilitating entomology incorporation practices. Teachers described insects as "inexpensive", "hardy", "small yet macroscopic", and "exempt" from research oversight making them "very, very useful test subjects" in the science classroom.

Many teachers noted that live insects could be acquired at no cost when collected from the local area or could be obtained at a "low cost" when purchased from a biological supply store, pet store, or bait shop making them "less expensive" than other potential test subjects.

With meager food, water, and space requirements, many teachers felt that insects were "kind of a maintenance-free animal system" that proved easy to care for in the classroom. One teacher explained, "With the mealworms and the beetles, their feeding, they have such a wide variety of foods that you can provide them with and they're almost drought-resistant. It's pretty wonderful so... if there's a little weekend or something I don't have to worry about my population crashing." Compared to other animals, living insects were viewed as requiring relatively little time commitment with one teacher commenting, “It's not something that you'd have to spend a whole lot of time feeding them. You have to feed and water them obviously but it's not like having some things that'll take a lot of care.” In addition, the limited space required to culture insects was viewed as a benefit with one teacher noting “you can have them in little fish bowls or little tanks or little vials and things like that.”

Aside from the ease with which insects could be cultured in the classroom, teachers discussed the importance that insect size and limited research oversight had on using insects rather than other model organisms in animal behavior experiments. While teachers appreciated the limited space that insects required, they also noted that insects were “macroscopic” and therefore it was “easy [for students] to see their behavior and their traits” during investigations. In addition to their size, teachers noted that “you can manipulate insects and it doesn’t ruffle anybody’s feathers”. One teacher explained that the use of insects and other invertebrates as test subjects was preferred over vertebrates due to the lack of research ethics oversight for invertebrates.

> “You know we have a research class in our school, so we have an institutional review committee-people who review projects done in the different laboratories- and you're exempt from that with insects as models. Mostly, it always applies to vertebrates.”

In rare cases, teachers noted that insect characteristics could function as a barrier to entomology incorporation. When housing live insects in a science classroom, containment of insect sounds and the insects themselves were two issues that teachers noted. In one case a teacher described how housing crickets was not sustainable due to their stridulation behavior.

"We tried to grow crickets in the classroom. And they just drove everybody on the first floor of the school crazy. They didn't escape, but they chirped all the time. So the guy in the next room was just going crazy. I had to get rid of the crickets."

Another teacher recounted containment issues when her students handled winged *Drosophila melanogaster*, the common fruit fly.

"There are just so many escapees with the kids handling them for the first time. And the anesthesia not always being that reliable. So, I would have various issues with the Drosophila."

Teachers' prior entomology experiences. Nearly all teachers discussed how prior entomology experiences facilitated entomology incorporation in their science instruction. Teachers discussed experiences in both formal and informal education settings impacting their incorporation practices.

Some teachers discussed having formal training or background in entomology such as taking courses for an undergraduate "minor" or "earning a Master's degree" in entomology. Other teachers mentioned earning a degree in an entomology-related field such as "plant and soil sciences", or "insect biochemistry ". Teachers often mentioned how having to take "a bunch of classes in entomology" contributed to their "technical background", "knowing a lot about it", or "having the knowledge" to teach about insects. In addition to their entomology knowledge base, formal entomology experiences provided teachers with "background materials like PowerPoints" that seemed to support teaching about entomology content.

In contrast, some teachers did not have entomology experience in a formal classroom, but they did have informal experiences that contributed to their interest in and knowledge about insects. Teachers mentioned a wide variety of informal experiences. One teacher discussed interning at a science center with Madagascar Hissing Cockroaches.

> "I interned at the [redacted] Science Center in [redacted]. It's the number one state science center. I was taught how to handle the Madagascar Hissing Cockroaches, so when I started teaching, it's always a wow factor, so I've always wanted to bring that into the classroom."

Other teachers discussed being drawn to entomology-related hobbies as children or adults. One teacher recounted the common childhood experience of collecting all manner of natural objects.

> "I think as a kid growing up my folks encouraged me to be curious about things. I had rock collections or mineral collections, I had shell collections and I had insect collections."

Another teacher described a specific passion for fly fishing and aquatic insects.

> "Yeah. I've been a fly fisherman and fly tie-er for a long time. I think I have maybe a little bit of my own interest and passion about insects."

While teachers with informal experience did note that their "personal knowledge" made insect incorporation possible and helped them to feel "equipped to handle kids' questions", teachers more commonly discussed the impact that informal experiences had on affective outcomes such as "interest" or "passion" for insects.

Impact of institutional or policy directives. Teachers discussed how institutional or policy directives such as state-mandated standards or testing and required course content impacted their entomology incorporation practices. In some cases, these directives facilitated inclusion of entomology content and in other cases they acted as a barrier, excluding entomology from science instruction.

In alignment with findings from the survey, some teachers echoed the sentiment that they did not feel entomology-related content supported state-mandated standards and this misalignment represented a barrier to incorporation. One teacher explained how the highly structured nature of state testing effectively guaranteed the inclusion of certain science topics to the exclusion of others, including entomology.

> “When you have a very rigid amount of material that you've got to cover because there's a state test involved. If that's the case you've got to cover the information that the state is going to be testing the students on. And there's no entomology on the state test.”

The teacher goes on to state how the focus on the state testing differs from state to state, but that in states where testing is viewed as especially important, some content, including entomology, that would be of interest to students is sometimes excluded.

> “I think that it's other things that are happening in the educational realm. I think that so much emphasis is now being placed on state tests in certain states. The one I was talking about in [redacted], we didn't ever talk about the state science test. We did our job, we taught our science, had the students take the test and they did very well, and live in another state, and [redacted] is a prime example, we're so

> attuned to the test that I think we sometimes forget about all the other information that there is, especially in science, that would really interest our kids."

Other teachers explained how state guidelines have shifted away from studying animals and living organisms in biology. One teacher explained that on the state's keystone exam "we don't talk about animals, and when we do it's simply the dissection". Another teacher felt that studying animals had been replaced by studying humans and this negatively impacted the inclusion of entomology in science classrooms.

> "As with probably every other state, we all have our state guideline for mandated curriculum. In [my state] we call it the [redacted]. In that realm, as you go through, nowhere does it ever address the term insects. Nowhere does it ever tell us to spend more than a skimming point over taxonomy and we don't delve very much into the animal kingdom at all other than to say there are things that are vertebrates and things that are invertebrates, we spend an awful lot of time talking about people. It seems people are, according to [my state], a little bit more important."

Despite the organizational and policy barriers that negatively impacted teachers' entomology incorporation practices, several teachers also discussed how policies could also function to facilitate inclusion of entomology content in their science courses. One teacher indicated that in her vocational horticulture course, entomology was covered "in our state framework." A more common occurrence was the inclusion of entomology as part of Advanced Placement (AP) coursework offered through College Board for college credit.

"I started teaching AP Biology II in my building, this is the second year that I've taught it, and one of the AP labs is the animal behavior lab, and that's where we work with pill bugs, and another AP Biology lab is the *Daphnia* circulatory system, so we use both of those animals. For me, it's probably the setup of the AP lab manual that AP teachers are required to use. Normally, we have to participate in twelve labs, and then basically they give you these twelve and then they tell you that you can then adapt them more to your classroom or maybe more to your geological area, things like that, so there are alternatives to that."

Availability of instructional time. While not commonly discussed, several teachers did explicitly point to limited instructional time as a potential barrier to entomology incorporation, but teachers had different opinions on the perceived severity of this barrier.

In one case, a teacher discussed time as an outright barrier to any entomology content being covered in her science classroom.

"I've been teaching for, this is my 25th year. I started teaching in 1986. I've taken a couple years off with kids in between, and in that time, I went from covering all that material to leaving out what I would think is a good chunk of material that might interest some of our kids, and insects is one of those things that kind of falls by the wayside because of time."

Another teacher explained how time limited his ability to study entomology in depth but did not outright exclude teaching entomology in the classroom.

"I guess we don't get real deep into it as far as trying to study them and things like that. I mean, it'd be great if I could but it's just not the best use of the time."

In another case, a teacher described an extensive (i.e. months-long) project involving insects in a course that was structured to allow for “open inquiry” and students were given “basically two or three months to do it at your own time and your own speed.” Based on teachers differing perspectives, time would seem to be a factor that impacts entomology incorporation largely based on the course being taught and the flexibility that teachers feel they are afforded in covering required content.

RQ3: How can the entomology community help support high quality entomology incorporation in U.S. secondary science instruction?

Quantitative Results

Preferred resources, training, and supports. When asked to rank six potential resources in terms of their usefulness to future entomology incorporation, teachers ranked lesson plans aligned to state or national standards and professional development workshops teaching how to use insects to support inquiry as the top two most useful resources (Table 4.5).

Table 4.5. Teacher rankings of preferred resources

Rank	Resource	Mean rank ± SE
1	Lesson plans aligned with standards	2.61 ± 0.122
2	Professional development on using insects in inquiry	2.64 ± 0.111
3	Professional entomologists visiting the classroom	3.75 ± 0.123
4	Live insects available for check-out	3.78 ± 0.106
5	Insect collecting supplies available for check-out	4.00 ± 0.099
6	Guide on insect care	4.22 ± 0.104

Qualitative Findings

Quantitative results indicated that teacher preference for standards-based lessons plans to support entomology incorporation efforts. Based on this result, qualitative interviews focused on gathering teacher perspectives on how lesson plans would need to be designed to meet teachers' needs when incorporating entomology into future science instruction.

Designing curriculum resources to meet teachers' needs. Teachers described several ways that entomology curriculum resources could be designed to better serve their needs and therefore, prove useful in supporting future entomology incorporation.

Supports student learning. Teachers most commonly discussed recommendations for how student learning could be better supported in future entomology lesson plans. Teachers explained that effective lessons should hold students' interest, support student-driven investigations, present content appropriate for high school science courses, and support diverse learners.

Many teachers discussed a want for lessons that "excite", "interest", "hook" or "engage" students. In many cases, teachers perceived a high level of physical activity to be associated with increased student engagement. Teachers preferred lessons with "interactive" "hands-on" elements or students "doing something" as opposed to "seat work", "lab reports", or "just reading and either regurgitating something they read or answering a sheet of questions". Teachers discussed "going outside", "crime scene type things", "lots and lots of activities" and "interactive technology pieces" as supporting greater student interest. As one teacher explained, "You know, it has to grab them. They have to want to do it and get excited about it. I look for hands-on types of things a lot rather than seat time."

For some teachers, student engagement was also closely tied with inquiry-based learning approaches dominated by student-driven investigations. As one teacher explained, "I'm looking for a high degree of inquiry, because I think the more inquiry and discovery that's built into it, the more engagement and learning that we see." Settled science and "cookbook" labs were unappealing to many teachers, and the importance of the learning process being "student-focused" with "students coming up with their own questions" and "carrying out the process" was often mentioned. As one teacher explained, "I look for something that I could turn into inquiry where it's not already there.

I like them leading the question. I want them to be thinking of how to test something. I want them to come up with questions. I want them to figure out how to test something, what more could we do with the bug, with any lesson."

In addition to focusing on *how* students learn the material, teachers discussed the importance of *what* content was presented in lessons. Teachers described the need for lessons to address science content required by the state standards and be presented at a level and depth appropriate for the high school science classroom. One teacher explained, "It needs to be something that I am supposed to be teaching because there's such limited time in the classroom, I have to make sure I'm hitting all the standards." In addition, some teachers explained that while many entomology lessons are available, those lessons that are suitable for use at the high school level are "difficult to find". One teacher explained, "I don't know that they're ever readily available. I mean, yeah you can find the parts of insects and the kinds of things if I wanted to get into some detail like that, but I'm not doing that really. And the level that I'm doing it at, you probably can't find anything."

While not commonly mentioned, several teachers discussed the importance of lessons plans being designed for differentiated learning to support diverse learners. One teacher highlighted the importance of visual and auditory learning modalities to meet the needs of all students.

> "Definitely a hands-on activity is part of it. If there is a video, like a visual or an auditory that I can mix in, that way I can kind of target everyone in the class. If we can go outside, that's even better."

Another teacher discussed how if reading was presented in a lesson, it would need to be "tiered" with "the major information…at a level that everyone can get. Then, if any supplementary information, like the advanced stuff, that's gotta be over on the side. Or as a separate document just for the advanced kids." Lastly, one teacher described how he structured student engagement in scientific practices for an animal behavior experiment to make it work for two courses of different levels.

> "We are going to do a lab in a couple of weeks which it's a behavior kind of laboratory, so we hatch these eggs from the cabbage white butterfly. And you give them different kinds of cabbage or lettuce or whatever and then you watch to see how many larvae go to a different leaf. So, for sophomore, they could just count them and make a bar chart. For a Bio 2, they have to propose a null hypothesis and then with the Chi-Square statistic, you know, test the hypothesis and then, you know, depending on acceptance or rejection, then they have to come up with an alternative hypothesis and propose a mechanism to test that. So that's like the second level of the same thing."

Supports teacher facilitation. In addition to providing a learning procedure to support student learning, lessons plans can also provide valuable information and tools intended to support the teacher in successfully enacting the lesson. Teachers discussed how including assessments and necessary entomology background information would support teachers in using newly developed lesson plans.

While some teachers described assessments as "nice to have, but not necessary", this did not mean that learning was not evaluated. Rather, teachers described being able to "build it myself" or "create my own", but in cases where assessments were provided one teacher explained, "That's always nice if something is available that I can modify." In another case, a teacher working in a school where a single course could have 350 students across 16 sections explained that assessments allowed for continuity across multiple class periods and were a necessity if the lesson were to be incorporated into instruction.

> "Now a lot of people are very gung-ho or rigorous I guess you could say was a better term for having answer keys for things. So, a lesson plan that has analysis questions and so on would have to have an answer key as well to have it accepted."

Some teachers acknowledged that they were likely not the "average biology teacher" in terms of their familiarity and knowledge with entomology and therefore discussed the need for "clearly written" entomology background information to be included in a lesson plan. Teachers highlighted that background information would be especially important if the lesson plan called for culturing or working with live insects. Multiple teachers addressed the importance of providing a "detailed materials and methods section" on "handling techniques, culture techniques, feeding, lifecycle information" and "how to care for the critters". One teacher went on to explain that without this valuable understanding teachers may be "hesitant to bring living things into their rooms if they think they are going to be very labor intensive as far as keeping them alive and stuff. And you certainly don't want a jug of dead stuff when you are supposed to have a jug of live stuff." This sentiment was echoed by another teacher who agreed, "I would want a care package guideline. The only reason I have the Madagascar Cockroaches is because I know how to take care of them. I feel confident that I can keep them alive for a while. Like any other insect, I wouldn't be sure at first, so I would like a care package of how to take care of them sufficiently."

Provides new or updated entomology content. Most teachers mentioned h low self-created lessons or newly developed entomology lessons could help to keep their course content up-to-date or provide new ideas or ways of presenting traditional content.

Teachers recognized the value of keeping their science instruction up-to-date but also recognized that this was sometimes difficult to do. A teacher lamented, “since I'm not in grad school anymore I don't keep as right on the cutting edge as I used to, but I try to keep up with all that I can.” One teacher explained how she used information gleaned from her required pesticide trainings to meet a need for current invasive species content in her vocational horticulture course.

> “If you have a pesticide license, which all horticulture teachers are required to have as part of their teaching license, you go to so many classes a year through the pesticide department of the state. And each class you take, they're all on different things, you pick what you want to go to, you receive credits to maintain your license. So, when I learn new things at those classes, I can make a lesson plan off of it so if they tell us about a new invasive species, I'll take the information that they gave me, and I can make a lesson plan off that. So, then I keep them up-to-date.”

Another teacher felt that newly constructed lesson plans created by entomology professionals could help “just updating” their current offerings to present accurate and up-to-date entomology findings.

In addition to keeping course content current, several teachers viewed new entomology lesson plans as an opportunity to improve their entomology incorporation practices. Several teachers described wanting “ideas for teaching fundamental concepts in a new way”. One such teacher explained that she felt different from other teachers in this way.

> “I teach with a lot of people who want to do the same old, same old, same old, and I'm not like that. I want to do something different all the time.”

Despite this teacher feeling alone in her want for change, this sentiment was popular, with nearly all teachers viewing lesson plans as a way to “see what other people are doing”, gain “some ideas that I don’t have already”, “try something new”, or teach “something that I didn’t have to invent”. In one particularly striking interview, a teacher explained that improvement is what teaching is all about and other teachers are often their source of inspiration.

> “I don't know everything. I'll be the first one to say that. There's always better ways to do things. Of course ... I guess they say teachers are the biggest thieves in the world or something like that, I don't know how to put it. Borrowers, maybe that's a better word than thieves. Yeah. I'm always wanting to see how people do things different, because if there's a better way to do something than what I'm doing, you bet. I'm not afraid of ditching what I've got for something better. That's how you get better at things. You can't think of everything. Yeah, if I had availability to some different type of lesson plan, some of them I may have to modify a little bit for our situation, but it might be a different way of approaching the problem, it may be a lot better. Yeah, I would be open to that.”

Works within constraints. Finally, teachers described how having limited planning and instructional time, financial resources, and available equipment were all potential barriers to entomology incorporation, but that these are areas where well-designed entomology lesson plans could prove useful.

One of the most common challenges teachers faced was the inconvenience of planning instruction. Teachers viewed well-designed lesson plans as “saving time” with one teacher admitting that “there just aren't enough hours in the day anymore. If I had something already made that I could look at, yeah I would love it.” While many teachers discussed how it was rare to find a lesson plan that would work without “adapting” or “modifying” the lessons to meet their classroom needs, teachers often acknowledged the value of existing plans as a foundation to build upon.

> “I think that collaboration, that sharing of lesson plans, is very, very helpful, because then I don't feel like I have to go out and start from scratch or build it myself, where if I find a good lesson plan, like I said, normally you still have to make adaptations, but, again, I'm not starting at zero. I already have a basis, and then I can build on it.”

Spending time looking for reliable lesson plans was another concern with one teacher explaining, “Normally I am piecing together labs, so if I had one that maybe has been proven to work well… I mean, I'm not the only teacher who teaches biology in my building, so we as a group, we will discuss, "What lab procedure did you use, or how did you change this?"

Aside from planning time, many teachers expressed feeling a time crunch in the classroom “trying to fit this in and get that information across”. In many cases, teachers mentioned the need for lesson plans to work within instructional limitations that include often short class periods and a curriculum packed with content. One teacher explained, “I only have them for 45 minutes every day, so if I do a lab, I have to be able to get everything done in the lab in 45 minutes." To fit within classroom time constraints, teachers expressed that the lesson "needs to be not too complicated to set up because I'm very busy" and the instruction should be "not terribly long, drawn out type of individual lessons".

Lastly, teachers discussed the dual constraints posed by shrinking budgets and the need for specialized equipment and consumable supplies in the science classroom. One teacher explained how selection of lab experiments was often based on obtaining materials with limited financial means.

> "We are not a wealthy school district so I like to have things that I can normally find if I need to, so I'll find things that are like kitchen chemistry lab experiments that we can do."

Even in cases where "money isn't an issue" teachers explain that the materials they purchase have "to be reasonably priced, whatever I buy."

CHAPTER 5: DISCUSSION AND CONCLUSIONS

The purpose of this study was to use a mixed methods approach including quantitative survey research and basic qualitative methods to (1) describe current entomology education efforts in a representative sample of U.S. secondary science classrooms, (2) identify facilitators that support secondary science teachers' entomology incorporation practices and potential challenges that may hinder these efforts, and (3) elicit teacher perspectives on how K-12 entomology education resources or supports can be designed to meet teacher needs. This chapter presents a summary of findings and a discussion of implications and recommendations for future K-12 entomology education efforts.

Summary of Findings and Implications

RQ1: How can entomology incorporation be characterized in U.S. secondary science instruction?

In answering the first research question, findings from this study suggest that most U.S. secondary science teachers include entomology less than once a month in their science classrooms with a diversity of insect orders being presented. Teachers rely on a variety of curriculum and instructional supports with 81% using lesson plans and 43% incorporating live insects. Survey results also indicate that a variety of entomology topics, science concepts, and science practices are supported via incorporation of entomology content.

Current science education reform efforts call for students to engage in science and engineering practices in order to construct an understanding of core science ideas and cross-cutting concepts that are shared across the various science fields (NGSS Lead

States, 2013). Therefore, it is useful to determine if current entomology incorporation practices are used to support these instructional shifts. Quantitative results appear to support the assertion that entomology education supports student engagement in scientific practices and learning of science concepts in accordance with NGSS recommendations. In addition, findings from the qualitative strand shed light on several practices which are aligned with recommended instructional shifts in science education. For example, some teachers described their entomology incorporation practices as student-driven, inquiry-based learning experiences often involving live insects or pinned specimens in which students engaged in various science practices. These results suggest that some teachers are using NGSS-recommended instructional practices when incorporating entomology in secondary science classrooms. On the other hand, survey results also indicate that a high proportion of teachers showed a preference for professional development focused on using insects in inquiry. This finding would seem to suggest that many teachers are still looking for guidance in bringing their entomology incorporation practices into alignment with NGSS-recommended instructional shifts.

These findings are limited in several ways. First, survey data represent teachers' self-reported classroom practices and do not include triangulated data confirming these practices. Second, data from this study do not give a sense of frequency or quality of teachers' adoption of NGSS-recommended instructional shifts during presentation of entomology content. Based on these limitations, it is unclear to what extent entomology incorporation practices are in alignment with reform-based instructional practices.

Qualitative results also allowed for a more nuanced understanding of how entomology incorporation supports science literacy in the secondary science classroom.

Findings highlighted the value teachers placed on teaching broad science content *with* insects (i.e. developing students' science knowledge and skills, developing students' critical thinking skills, making content memorable, and connecting the classroom to the real world) while limited discussions focused on teaching *about* insects in the classroom (i.e. addressing students' misconceptions about insects). These findings may suggest that teachers prioritize using insects as teaching tools to support broader science understanding rather than promoting entomology literacy, per se.

Another interesting finding from the qualitative strand was the importance of both teacher and student emotional outcomes associated with entomology incorporation. It may not be surprising that insects were associated with emotional outcomes, given the strong emotional response that insects tend to evoke in humans. However, it is noteworthy that teachers mentioned largely positive rather than negative emotions in association with insect incorporation. Results indicated that entomology incorporation brought about student enjoyment or excitement for learning, helped students overcome fear or disgust, supported the development of empathy or concern for insects, and brought about teachers' enjoyment for teaching. This finding may suggest that secondary science classrooms present fewer attitudinal hurdles compared to elementary science classrooms when trying to integrate entomology education into science instruction.

Lastly, while qualitative findings indicate that inclusion of entomology content succeeds in cultivating empathy for insects in some cases, it is also possible that taking action on this empathy can result in unintended consequences. In several cases, teachers acknowledged the practice of releasing live insects or other arthropods that were not locally collected into the surrounding environment. While this practice was not widely reported, it is worth noting given the far-reaching impacts associated with the introduction and spread of invasive species. Entomology education resources should consider explicitly addressing this concern when lessons call for live insects to be sourced from commercial suppliers rather than collected locally.

Findings from this study add to the research literature by characterizing the state of entomology education including which insect orders are being presented, how often, for what purpose, and using which tools or resources in a representative sample of secondary science classrooms.

RQ2: Why do teachers choose to incorporate entomology into secondary science instruction?

In answering the second research question, findings indicated that factors influencing entomology incorporation practices are complicated. Despite previous literature positing that “attitude, background, and training” are the reasons why insects are not included in every K-12 classroom (Matthews et al., 1997), findings indicate that numerous factors are at play.

First, results indicated that secondary teachers hold generally positive attitudes toward insects and these attitudes are associated with different levels of entomology incorporation. A high proportion of secondary science teachers are comfortable handling insects and find insects’ appearance appealing while also affirming presentation of entomology content in their science instruction. Results show that teachers who reported using insects once a month or more in their teaching rated insect appearance as being appealing 26 times as often as unappealing. Additionally, teachers who reported presenting five or more insect types in their science classroom rated insect appearance as being appealing 20 times as often as unappealing. Lastly, teachers who reported that entomology incorporation supported a high level of engagement in science practices reported feeling comfortable handling insects nearly 11 times more often than uncomfortable. These finding are in contrast with previous studies of pre-service elementary teachers which found patterns of teachers' negative beliefs and attitudes towards invertebrates negatively influencing their reported willingness to use insects in future science instruction (Wagler & Wagler, 2011, 2012). While elementary pre-service teachers and secondary in-service teachers appear to hold different attitudes toward insects, these results substantiate the theory that teachers' attitudes have an impact on entomology incorporation.

Next, results suggest that teachers' lack of background or training in entomology may not function as a barrier to entomology incorporation in secondary science classrooms but having entomology experiences may facilitate a greater degree of incorporation. Findings showed that even though only approximately 1/3 of teachers had formal or informal entomology experiences, an overwhelming majority of teachers (88%) reported incorporating entomology into their science classrooms. In addition, despite 39% of teachers reporting a lack of adequate training, most teachers felt confident in their ability to care for and teach about insects. Taken together, these results would suggest that having entomology training or background is not a prerequisite for teachers to present entomology content in secondary science classrooms. However, study results did indicate that prior entomology experiences are related to the level at which incorporation practices are implemented. Results of cross tabulation analysis found that teachers having experienced a professional development with insects reported supporting a high level of science practices with entomology content five times as often as a low level. The impact and effectiveness of teacher professional development has been shown to be widely variable, however, well-designed professional development experiences have been shown to positively influence teachers' knowledge and instructional practices (National Academies of Sciences, Engineering, and Medicine, 2016; S. M. Wilson, 2013). Likewise, these results confirm prior research showing the positive impact that entomology-based professional development experiences have on teachers' instructional practice (Golick & Heng-Moss, 2013; Golick et al., 2010).

While attitude, background, and training appear to impact teachers' incorporation practices, findings suggest that external factors outside of teachers' control also play a key role in entomology content being included or excluded from secondary science classrooms. Survey results indicated that a perceived lack of alignment with state or national science standards and lack of fit with approved curriculum are the most common barriers to entomology incorporation. Survey results also indicated a lack of time (43%) and limited access to standards-aligned, entomology instructional resources (33%) present challenges for a sizeable portion of teachers. In teacher interviews, availability of instructional time in the classroom, prior entomology experiences, access to necessary entomology resources, insect characteristics, and organizational or policy directives emerged as key themes relating to facilitation of or barriers to entomology incorporation. Four of the five themes from the qualitative strand aligned with quantitative results strengthening confidence in these findings. These findings support national survey research indicating that many teachers perceive their ability to make instructional and curricular decisions is limited (Banilower et al., 2018). The 2018 National Survey of

Science and Mathematics Education found that a limited number of secondary science teachers report having strong control over the amount of instructional time to spend on each topic (48%), selecting curriculum materials (36%), and selecting content, topics, or skills to be taught (34%) (Banilower et al., 2018).

Given the impact of external factors, it may be helpful to view K-12 entomology education in the context of science education standards and reform policies. Contemporary U.S. education legislation requires states to adopt challenging academic standards and assess student performance according to these standards (Every Student Succeeds Act (ESSA) of 2015, 2015). To comply with this directive, science teachers are called upon to select and implement a science curriculum that supports legally-mandated science standards. At the high school level, research suggests that most teachers have a good deal of freedom to design their curriculum to meet their individual needs. The 2018 National Survey of Science and Mathematics Education found that 86% of high school teachers report using self-created units or lessons at least once a week compared to only 14% of teachers using state, county, district, or diocese-developed units or lessons weekly (Banilower et al., 2018).

Despite this freedom, findings suggest that teachers select and implement entomology content largely based on its perceived ability to serve broader science education goals in alignment with state or national science standards. For example, on average, teachers reported incorporating more than five different insect groups into science instruction, however, flies (order Diptera) were the most common insect group used. The high incidence of flies being presented may be due primarily to the emphasis placed on genetics as a core idea at the high school level in science education standards

(NGSS Lead States, 2013) and *Drosophila melanogaster* (i.e., the common fruit fly) as an important model organism used in genetic studies. Furthermore, while a large proportion of teachers reported using insects to support teaching various standards-related core ideas, concepts, and practices, results indicated that several entomology topics identified as important by professional entomologists (e.g. aesthetic value of insects, insect products, insect-related decision-making processes) (Pearson et al., 2007) do not directly align with state or national science standards. These topics were reported as being taught in fewer classrooms.

Findings from this study provide evidence that a host of factors including teachers' attitudes and beliefs, prior entomology education experiences, time, and access to standards-aligned entomology lessons function to facilitate or inhibit entomology education at secondary grade levels and contribute a more nuanced perspective of the realities and contexts that influence teachers' entomology incorporation practices.

RQ3: How can the entomology community help support high quality entomology incorporation in U.S. secondary science instruction?

In answering the third research question, findings indicate teachers' preference for standards-aligned lesson plans and professional development teaching how to use insects to support inquiry, a pillar of science education standards (National Research Council, 1996; NGSS Lead States, 2013). Survey results support the supposition that creating standards-aligned lesson plans and offering professional development or training opportunities would expand or improve entomology incorporation practices in secondary science classrooms.

The use of curriculum materials has been shown to impact teacher characteristics, practices, and student learning (reviewed in Davis, Janssen, & Driel, 2016). Therefore, it can be reasoned that if appropriate K-12 entomology curriculum materials are accessible and implemented by teachers, entomology education efforts may be better served in secondary science classrooms. However, this argument hinges on the availability, awareness, and adoption of quality entomology curriculum materials.

Despite prior literature claiming that “an abundance of instructional resources using insects and other arthropods has been … developed” (Matthews et al., 1997), one-third of teachers disagreed that plenty of quality lesson plans were available to support entomology education in their secondary science classrooms. This apparent conflict in opinion may point to issues of accessibility or awareness rather than existence of entomology instructional resources. As previously noted, numerous entomology lesson plans have been published in peer-reviewed practitioner journals such as American Biology Teacher, Science Scope, and Science Teacher. However, access to these lesson plans comes at a cost either via direct purchase or via membership to the national science education association which publishes the journal. It is unclear how many U.S. secondary science teachers have access to such publications. However, the National Science Teacher Association reported a 2019 membership of 50,000 science teachers, science supervisors, administrators, scientists, business and industry representatives and others involved in science education (“NSTA Overview,” n.d.). This represents approximately 1% of the estimated 3.7 million public and private K-12 school teachers in the U.S. (U.S. Department of Education, National Center for Education Statistics, 2017). If access to entomology lesson plans is reliant on secondary science teachers’ access to practitioner journals, it is reasonable to conclude that many teachers may be unable to access or are unaware of the availability of these lesson plans.

Cross tabulation analysis results from this study indicate that teachers' belief in lack of plentiful quality resources may represent a barrier to higher levels of entomology incorporation. Results showed that teachers who incorporated insects less than once a month disagreed that plenty of lesson plans were available nearly four times as often as teachers who incorporated insects once a month or more. In addition, teachers supporting four or fewer entomology topics via entomology content reported disagreeing that plenty of quality lesson plans were available more than two times as often as agreeing. Lastly, teachers supporting four or fewer science concepts via entomology content reported disagreeing that plenty of quality lesson plans are available over three times as often as agreeing.

Aside from teachers' beliefs about availability of quality lesson plans, teachers' use of lesson plans was shown to be associated with higher levels of entomology topics, science concepts, and science practices. Cross tabulation analysis results show that teachers who supported a high level of entomology topics reported using a lesson plan eight times more often than not. Additionally, teachers who supported a high level of science concepts reported using a lesson plan five times more often than not. Finally, teachers who supported a high level of science practices reported using a lesson plan ten times more often than not. These findings suggest that ensuring teachers' have access to entomology lesson plans may support science literacy via presentation of entomology content to a greater degree.

Overall, results from this study are in agreement with prior research suggesting that curriculum materials can have an impact on teacher practice (reviewed in Davis et al., 2016). However, despite evidence of a relationship existing between teacher practice and curriculum materials, the data do not allow for elaboration such as identifying which curriculum materials are used, if available materials are structured to support reform-based teaching approaches, or how use of entomology curriculum materials impacts teacher practice. Given this limitation, the process and impacts of teacher enactment of entomology curriculum materials warrants further investigation.

In addition to quantitative results, findings from the qualitative strand provide insight into teachers' preference for entomology lesson plans that are designed to support active learning approaches, provide assessments and necessary entomology background information to support teacher success, provide up-to-date content and new approaches when presenting traditional content, and work within constraints of limited planning and instructional time, classroom budget, and available equipment. These findings could prove useful in planning future curriculum development efforts to best meet teachers' explicitly expressed needs.

While curriculum materials provide concrete and tangible avenues for teachers to enact changes in science instruction, it is also important to recognize that curriculum materials alone do not generate change in the classroom (Powell & Anderson, 2002). Rather, curriculum materials are 'inert' tools that teachers must put into action to bring about change. Therefore, aside from providing curriculum materials, it is important to consider how professional development and entomology learning experiences may influence teachers' instructional practices.

Results from this study are in agreement with literature indicating that teachers' knowledge and beliefs influence instructional practices in the classroom (Borko & Putnam, 1996; Borko et al., 2008; Wallace & Louden, 1998). Results from cross tabulation analysis show that teachers' belief in having received adequate training was associated with higher levels of entomology incorporation. First, teachers who incorporated insects once a month or more agreed that they had received adequate training to teach about insects over two times as often as disagreed. In addition, teachers who incorporated five or more insect types agreed that they had received adequate training to teach about insects nearly three times as often as disagreed. Lastly, teachers who supported five or more science practices via entomology content agreed that they had received adequate training three and a half times as often as teachers who supported four or fewer science practices with entomology content.

In order to influence teachers' knowledge and beliefs to support sustained changes in instructional practice, professional development including formal teacher training programs, continuing education courses, and workshops or trainings are often implemented (Borko, 2004). Results from this study may support prior research suggesting that professional development can have on positive impact on teacher practice as it relates to incorporating entomology content (Golick & Heng-Moss, 2013; Golick et al., 2010). As reported previously, results of cross tabulation analysis found that teachers having experienced a professional development with insects reported supporting a high level of science practices with entomology content five times as often as a low level. However, these results only suggest that a relationship exists between teachers' reported professional development experience with insects and higher levels of entomology incorporation, but does not examine the nature of this relationship. Future studies on teacher professional development involving insects could be conducted to determine if such experiences have any impact on teachers' knowledge and beliefs.

Findings from this study provide evidence for the adoption of strategies to support future entomology education efforts and offer guidance for the development of instructional resources or supports including standards-aligned lesson plans and professional development opportunities that support inquiry-based approaches to using insects in secondary science classrooms.

Recommendations

Recommendations outlined here are directed primary at entomology professionals affiliated with a university, zoo, museum, or non-profit organizations. It is assumed that entomology professionals working in these settings 1) possess appropriate entomology knowledge, skills, and experiences, 2) have a vested interest in improving entomology education efforts, and 3) have the freedom to collaborate with teachers and school districts to enact lasting change. Recommendations are based on largely on findings from the third research question centered on supporting the creation of tools or resources that support high quality entomology instruction, however, recommendations also draw upon findings from the first two research questions.

Knowledge and insights gleaned from this study come directly from those who are in the best position to pinpoint obstacles and put forth feasible solutions to overcome identified barriers. Therefore, the entomology education community should prioritize the development of key resources (i.e. standards-aligned lesson plans and professional development opportunities focused on using inquiry-based approaches with insects) in alignment with national science education reform efforts to overcome stated concerns and to better meet the needs of U.S. secondary science teachers.

Create and Distribute Standards-Aligned Lesson Plans and Resources

Findings from this study underscore the need for the creation and distribution of easily accessible, standards-aligned lesson plans to support high levels of entomology incorporation in secondary science classrooms. If new entomology curriculum materials are to remain relevant and meet the evolving needs of today's science educators, they will need to be designed to reflect fundamental shifts expressed in current science education reform documents (National Research Council, 2012; NGSS Lead States, 2013). However, designing standards-aligned curriculum materials requires knowledge of education content standards that may be limited in many university entomology departments, zoos, museums, and non-profit organizations. Several strategies may help entomology education advocates to overcome limited science education expertise during the curriculum development process.

First, entomology literacy advocates such as university entomology departments and the Entomological Society of America's Education and Outreach Committee should consider partnering with professional curriculum developers, science education faculty or staff, or in-service science teachers with necessary expertise whenever possible. Not only does collaboration between entomologists and education experts increase the likelihood of developing scientifically accurate resources that integrate entomology literacy topics (Pearson et al., 2007) in alignment with core science ideas, concepts, and practices (NGSS Lead States, 2013), but cultivating relationships within the education community may also increase teacher awareness of available resources.

Next, entomologists may utilize freely-available rubrics to evaluate alignment of lessons and units to the NGSS. Available rubrics include the NGSS Lesson Screener from the National Science Teachers Association (NSTA) ("NGSS Lesson Screener," n.d.) or Educators Evaluating the Quality of Instructional Productions (EQuIP) Rubric for Science (Achieve and National Science Teachers Association, 2014). The use of evaluation rubrics will benefit curriculum development and adoption efforts in several ways. Rubrics will provide an objective means of evaluating resource quality and provide feedback to curriculum creators on areas for improvement. Also, evaluation tools will provide no-cost guidance to professional entomologists who are unfamiliar with recommended instructional practices in K-12 science education. Lastly, making the process of evaluation explicit and apparent to end users will help to assure teachers of the quality and usability of entomology curriculum materials in their secondary science classrooms.

Once curriculum materials are developed in alignment with state or national science standards, developers should consider maximizing resource accessibility and distribution. Curriculum creators can submit lessons or units for publication in practitioner journals such as American Biology Teacher, Science Scope, or Science Teacher. A major benefit of publication in a practitioner journal is the peer review process which helps to ensure quality resources are being distributed. While the unfamiliar format and language used in practitioner journals may present barriers for professional entomologists who are accustomed to publishing in technical journals, Richardson (2010) provides advice on overcoming these challenges including selecting an appropriate journal for dissemination and collaborating and co-authoring publications with education professionals who possess expertise aligning with the journal's focus. Another option to maximize accessibility and awareness of curriculum materials is to submit lessons to a trusted digital resource repository such as the Classroom Resources database found on the National Science Teachers Association website or the Curriculum Matrix found on the National Agriculture in the Classroom website. High-traffic education sites such as these offer teachers a "one-stop-shop" for free, vetted curriculum materials to use in their classrooms. University-affiliated faculty or staff may also have the option to publish lesson plans in their university's digital repository. While teachers may not frequent university digital repositories looking for curriculum materials, this option provides a no-cost, reliable, world-wide electronic option for accessing curriculum materials on an on-going basis and prevents teachers from losing access to materials due to a broken web address.

In the long-term, it is recommended that entomology education entities work together to develop an online web portal providing teachers with access to a centralized database of searchable resources. Efforts should also be undertaken to establish an evaluation procedure for ensuring distribution of scientifically accurate and NGSS-aligned entomology resources via the centralized hub. Driving teacher traffic to a single entomology education web portal would facilitate easy access to a curated collection of trusted curriculum materials. The website could also be designed to cultivate collaboration and sharing among a community of entomology education practitioners via message boards, social networking, or other means of online communication.

In cases where professional entomologists do not have the time or inclination to engage in development of standards-aligned lesson plans, it is possible that teachers' needs may be served in other ways. In 1976, a successful collaboration between the National Association of Biology Teachers and the Education Committee of the Entomological Society of America resulted in publication of an issue of American Biology Teacher, a practitioner journal for secondary science teachers, focused entirely on entomology (Creager, 1976). Based on the high proportion of teachers in this study who reported creating their own lesson plans and previous survey research indicating secondary science teachers' regular use of self-created lesson plans (Banilower et al., 2018), it is possible that essential entomology background information presented in a special entomology edition of a practitioner journal could be utilized by teachers to create their own entomology resources.

Offer Inquiry-Based Professional Development Workshops

Study findings indicated that both living insects and preserved or pinned specimens offer valuable teaching tools for supporting inquiry-based approaches in secondary science classrooms. However, findings also suggest that most teachers lack prior professional development experiences involving insects and additional training is needed to broaden the use of entomology-related inquiry in the science classroom. To support teachers' integration of entomology incorporation practices with reform-based approaches such as inquiry-based learning, it is recommended that high-quality professional development workshop opportunities are created and delivered.

To support long-term adoption of entomology incorporation practices, professional development offerings should be designed and implemented in accordance with recommendations for effective programming. Synthesis of research findings of teacher professional development across disciplines has yielded a list of key features associated with successful interventions including a focus on subject matter content, engagement in active learning, coherence with school, district, and state policy, adequate duration, and collective participation (Desimone, 2009). To meet the need for presentation of entomology-specific content knowledge as well as pedagogical content knowledge, it is recommended that professional entomologists and education professionals collaborate during the design and implementation of professional development experiences. Previous successful collaborations of this nature involving university departments and faculty and state or local K-12 education entities (e.g. school districts, regional education service units, state departments of education, etc.) have been demonstrated and have received grant funding.

Findings from this study demonstrated that the use of live insects supports a high level of student engagement in diverse science practices and can function as a vehicle for student-driven investigations. Therefore, professional development should provide instruction and/or resources on successful strategies for working with live insects including various collection techniques, insect rearing and containment procedures, ethical research practices, and humane euthanasia protocols. This recommendation would benefit from the involvement of professional entomologists or other knowledgeable individuals possessing the necessary knowledge and skills to provide teachers with guidance on rearing and care for insects in a classroom environment.

In addition to providing teachers with training on insect care and handling, professional development experiences should be designed to assist teachers in moving beyond using live insects' shock value to simply capture student attention. It is recommended that professional development experiences be designed to allow teachers to experience inquiry-based approaches and reflect on the value such practices bring to the science classroom. However, incorporating reflective practice into professional development requires a considered approach with adequate time provided to reflect on learned practices. In the past, university-affiliated and grant-funded professional development opportunities have been offered (e.g., Entomological Foundation's STEM Bugs, Bugs in the Classroom, Bugging Out! Teaching with Insects, etc.). Workshops like these generally provide positive, short-term experiences for teachers. However, long-term teacher emersion experiences in professional development programs are recommended to promote sustained shifts in secondary science teacher practice (Desimone, 2009; Loucks-Horsley, 2010). To support teachers' sustained engagement with inquiry-based approaches involving insects, we suggest that entomology education organizations or university entomology departments cultivate strong working relationships with local schools, districts, and educational service units to provide teachers with continual professional development opportunities to expand their entomology expertise.

Lastly, recent reports of declining insect biodiversity have raised the alarm for conservation action (Basset & Lamarre, 2019; Hallmann et al., 2017). Investment in invertebrate conservation efforts will hinge on future generations understanding the threats to insect diversity, but also valuing insect life. It is through increased understanding and appreciation of insects and other invertebrates that conservation action may become a reality. Findings from this study suggest that presentation of entomology in formal secondary science classrooms offer an opportunity not only to impact student knowledge, but also student affect. Results indicate that teachers present entomology not only to support educational outcomes, but also to support positive emotional outcomes for themselves and their students. Therefore, it may prove valuable to enact informal entomology education experiences that focus on supporting teachers' enjoyment, appreciation, and attitude toward insects and other invertebrates to capitalize on the influence that emotion can have in impacting teachers' future entomology incorporation.

Limitations

Entomology could be considered a field of specific interest for a limited number of secondary science teachers and this specificity could have resulted in non-response bias in our survey sample. If teachers who do not include entomology in their science instruction were less likely to respond to the survey, this fact may prevent generalization of the study results to characterize entomology incorporation in U.S. secondary science classrooms as a whole. However, comparisons of the survey sample with known parameters for national teacher and school demographics suggest that the survey does provide information about entomology incorporation practices in a representative sample of U.S. secondary life science classrooms.

The decision to purposefully select teachers reporting high levels of entomology incorporation practices as a majority of the sample included in the qualitative strand may limit understanding of barriers to incorporation if we assume that teachers reporting higher levels of incorporation encountered fewer barriers. This decision was made in order to ensure that most teachers interviewed during the qualitative strand would have a wealth of entomology incorporation experiences to share, however, including a larger pool of teachers reporting more typical, low-level of entomology incorporation practices may have highlighted additional barriers to incorporation that are not represented in the findings presented here.

Another limitation of this study is that findings are largely exploratory and descriptive rather than explanatory in nature due to limited empirical data available on secondary science teachers' entomology incorporation practices. The use of inferential statistics (i.e. cross tabulation analysis) did allow for testing if relationships exist between factors of interest and levels of entomology incorporation, however, this analysis is limited by its inability to indicate the nature of these relationships.

Suggestions for Future Research

Several findings from this dissertation warrant further investigation and multiple opportunities exist to conduct related future research with the aim of increasing understanding of K-12 entomology education. A logical next step would be to explore additional comparisons using the existing dataset followed by designing and conducting variations on this study to further explore entomology education practices in the K-12 arena.

First, comparative analyses could be conducted on the existing dataset. Quantitative data could be broken down by demographic criteria (i.e. teacher age, gender, years of teaching experience, education level, or school locale) and descriptive and inferential statistics calculated and compared to determine if entomology incorporation practices differ based on teacher affiliation with various demographic groups.

In addition to conducting further analysis of existing data, a potentially valuable next step could focus on exploring practices of teachers displaying more typical, low-level entomology incorporation practices. Findings from this study were based largely on perspectives from teachers displaying a high level of entomology incorporation. Follow-up interviews could be conducted with a larger, purposeful sample of willing participants from this study showing low levels of entomology incorporation. Data could be qualitatively analyzed, and comparisons made with findings from this study to determine if both groups report similar 1) educational and emotional outcomes stemming from incorporation, 2) barriers or challenges inhibiting incorporation practices, and 3) recommendations for elements to be included in future standards-aligned lesson plans.

Additional variations on this study could also be designed and conducted to further examine findings of interest from this study. Study results suggest the important role that science education reform efforts such as state-mandated science standards play in guiding teachers' entomology incorporation practices, but the results from this study do not sufficiently describe if entomology incorporation practices support teachers in enacting instructional shifts recommended in current science education reform. To address this limitation, a follow-up quantitative study could focus on how living insects, specifically, are used during entomology incorporation. In addition, a quantitative comparative study could be conducted in which data are collected from teachers working in states where entomology is included in the state framework (i.e. Georgia) and states where entomology is not included and analyzing results for significant differences between these populations. Findings would highlight the impact that science education reform policies play in influencing K-12 entomology education.

Lastly, findings from this study suggest that in-service secondary science teachers hold largely positive attitudes toward insects in contrast with previous findings focused on pre-service elementary teachers. These two populations differ in at least two respects, grade-level taught and in-the-field teaching experience. To further explore the impact that these variables may have on teacher attitudes and beliefs, data can be collected from pre-service secondary teachers and pre-service and in-service elementary teachers and analyzed for significant differences among teachers sampled from these populations. Findings would provide valuable information about factors influencing teachers' entomology beliefs and attitudes and guide development of strategies or supports which either make the most of teachers' positive attitudes or address teachers' negative attitudes.

Conclusions

Responses from a representative sample of U.S. secondary life science teachers indicate that a wide variety of insects are incorporated into life science instruction, but that incorporation generally takes place less than once a month. Despite limited instructional time dedicated to insects, teachers' entomology incorporation practices support a diversity of science concepts associated with science education standards and student engagement in inquiry-based science practices.

The extent to which teachers present entomology content is associated with a number of different factors including teachers' attitudes and beliefs, prior entomology experiences, and use of curriculum and instructional resources. A host of external factors including perceived alignment of entomology content with national or state science standards, time, insect characteristics, and access to necessary entomology resources act as facilitators of or barriers to entomology incorporation practices.

Teachers identified preferred resources for overcoming these barriers to be standards-aligned lesson plans and professional development workshops focused on using insects to support scientific inquiry. Based on these findings, a careful and considered approach is recommended in guiding the development and dissemination of standards-aligned entomology curriculum materials as well as creation and delivery of sustained professional development opportunities including experiences that support use of live insects and positive emotional outcomes for teachers.

Findings from this study broadly inform entomology education efforts by characterizing the state of entomology education in secondary science classrooms and providing a more nuanced understanding of teachers' incorporation practices and perceptions. Teacher-identified barriers to entomology incorporation and preferred resources provide valuable insights that shape evidence-based recommendations for the development of resources that meet teachers' needs while supporting high quality K-12 entomology education instruction.

REFERENCES

Achieve and National Science Teachers Association. (2014). *EQuIP rubric for lessons and units: Science*. Retrieved from https://www.nextgenscience.org/resources/equip-rubric-science

Alexander, D. (2012). *Buzz Into Action: The Insect Curriculum Guide for Grades K-4*. Arlington, VA: National Science Teachers Association - NSTA Press.

American Association for the Advancement of Science. (1989). *Science for all Americans: A Project 2061 report on literacy goals in science, mathematics, and technology* (Vol. 1). Oxford University Press.

Ashbrook, P. (2007a). Collards and caterpillars. *Science and Children*, *44*(8), 18–20.

Ashbrook, P. (2007b). Counting a culture of mealworms. *Science and Children*, *45*(2), 18–20.

Banilower, E. R., Smith, P. S., Malzahn, K. A., Plumley, C. L., Gordon, E. M., & Hayes, M. L. (2018). *Report of the 2018 NSSME+*. Retrieved from Horizon Research, Inc. website: http://horizon-research.com/NSSME/2018-nssme/research-products/reports/technical-report

Barrow, L. H. (2002). What do elementary students know about insects? *Journal of Elementary Science Education*, *14*(2), 53–60.

Basset, Y., & Lamarre, G. P. A. (2019). Toward a world that values insects. *Science*, *364*(6447), 1230–1231. https://doi.org/10.1126/science.aaw7071

Biggs, D., Miller, T., & Hall, D. (2006). There’s life in those dead logs! *Science and Children*, *43*(7), 36–41.

Blank, R., Langesen, D., & Petermann, A. (2007). *State Indicators of Science and Mathematics Education*. Retrieved from Council of Chief State School Officers website: http://www.ccsso.org/projects/Science_and_Mathematics_Education_Indicators/

Boardman, L. A., Zembal-Saul, C., Frazier, M., Appel, H., & Weiss, R. (1999). Enhancing the" Science" in Elementary Science Methods: A Collaborative Effort between Science Education and Entomology. *Proceedings of the Annual International Conference of the Association for the Education of Teachers in Science*, 1038–1050.

Borko, H. (2004). Professional development and teacher learning: Mapping the terrain. *Educational Researcher*, *33*(8), 3–15.

Borko, H., & Putnam, R. T. (1996). Learning to teach. In D. Berliner & R. Calfee (Eds.), *Handbook of educational psychology* (pp. 673–708). New York: Macmillan.

Borko, H., Roberts, S. A., & Shavelson, R. (2008). Teachers' decision making: From Alan J. Bishop to today. In *Critical issues in mathematics education* (pp. 37–67). Boston, MA: Springer.

Bowen, M. G. (2008). Investigating crickets: Observing animal exploratory behavior. *Science Activities: Classroom Projects and Curriculum Ideas*, *45*(3), 17–21.

Constible, J., & Lee, R. E. (2006). Awesome aggregations. *Science Teacher*, *73*(2), 44–50.

Creager, J. G. (1976). Why entomology? *The American Biology Teacher*, *38*(4), 203–203. https://doi.org/10.2307/4445546

Creswell, J. W. (2012). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research* (4th ed.). Upper Saddle River, NJ: Pearson Education Inc.

Creswell, J. W., & Plano Clark, V. L. (2011). *Designing and conducting mixed methods research*. Thousand Oaks, CA: SAGE Publications, Inc.

Damonte, K. (2005). Exploring insect vision. *Science and Children*, *42*(5), 47–48.

Davis, E. A., Janssen, F. J. J. M., & Driel, J. H. V. (2016). Teachers and science curriculum materials: Where we are and where we need to go. *Studies in Science Education*, *52*(2), 127–160. https://doi.org/10.1080/03057267.2016.1161701

Desimone, L. M. (2009). Improving impact studies of teachers' professional development: Toward better conceptualizations and measures. *Educational Researcher*, *38*(3), 181–199.

Dillman, D. A. (2009). *Internet, mail, and mixed-mode surveys: The tailored design method* (3rd ed). Hoboken, N.J: Wiley & Sons.

Eason, P. K., & LaManna, M. M. (2000). Testing folklore in the lab: Can common plants be used to repel insect pests? *American Biology Teacher*, *62*(6), 448–452.

Every Student Succeeds Act (ESSA) of 2015. , Pub. L. No. 114–95 (2015).

Fischang, W. J. (1976). Another wasted resource. *The American Biology Teacher*, *38*(4), 204–204. https://doi.org/10.2307/4445547

Gangwani, K., & Landin, J. (2018). The decline of insect representation in biology textbooks over time. *American Entomologist*, *64*(4), 252–257. https://doi.org/10.1093/ae/tmy064

Gates, D. M. (2002). Pond life magnified. *Science Scope*, *25*(8), 10–13.

Gates, D. M. (2005). Creating caddisfly cases. *Science Scope*, *29*(3), 54–56.

Gingrich, P. (1992). *Introductory statistics for the social sciences*. Retrieved from http://uregina.ca/~gingrich/text.htm

Golick, D. A., Ellis, M. D., & Beecham, B. (2006). Creating & evaluating artificial domiciles for bumble bees. *The American Biology Teacher*, *68*(4), 29–34. https://doi.org/10.1662/0002-7685(2006)68[e29:CEADFB]2.0.CO;2

Golick, D. A., & Heng-Moss, T. M. (2013). Insects as Educational Tools: An Online Course Teaching the Use of Insects as Instructional Tools. *American Entomologist*, *59*(3), 183–187. https://doi.org/10.1093/ae/59.3.183

Golick, D. A., Heng-Moss, T. M., & Ellis, M. D. (2010). Using insects to promote science inquiry in elementary classrooms. *NACTA Journal*, *54*(3). Retrieved from http://digitalcommons.unl.edu/entomologyfacpub/354/

Golick, D. A., Schlesselman, D. M., Ellis, M. D., & Brooks, D. W. (2003). Bumble Boosters: Students Doing Real Science. *Journal of Science Education and Technology*, *12*(2), 149–152. https://doi.org/10.1023/A:1023939811367

Groves, R. M., Fowler, F. J. Jr., Couper, M. P., Lepkowski, J. M., Singer, E., & Tourangeau, R. (Eds.). (2009). *Survey methodology* (2nd ed). Hoboken, N.J: Wiley.

Haefner, Leigh A., Friedrichsen, P. M., & Zembal-Saul, C. (2006). Teaching with insects: An applied life science course for supporting prospective elementary teachers' scientific inquiry. *The American Biology Teacher*, *68*(4), 206–212.

Haefner, Leigh Ann, & Zembal-Saul, C. (2004). Learning by doing? Prospective elementary teachers' developing understandings of scientific inquiry and science teaching and learning. *International Journal of Science Education*, *26*(13), 1653–1674.

Hallmann, C. A., Sorg, M., Jongejans, E., Siepel, H., Hofland, N., Schwan, H., … Kroon, H. de. (2017). More than 75 percent decline over 27 years in total flying insect biomass in protected areas. *PLOS ONE*, *12*(10), e0185809. https://doi.org/10.1371/journal.pone.0185809

Halverson, K. L., & Lankford, D. M. (2009). Science galls me: What is a niche anyway? *American Biology Teacher*, *71*(8), 483–491.

Hevel, G. (2005). How do insects help the environment? *Science and Children*, *42*(5), 44–45. Retrieved from ERIC. (62144198; EJ721539)

Heyborne, W. H., Fast, M., & Goodding, D. D. (2012). The Madagascar Hissing Cockroach: A New Model for Learning Insect Anatomy. *American Biology Teacher*, *74*(3), 185–189. Retrieved from ERIC. (1347461254; EJ997038)

Hobbie, A. (2000). Making connections with insect royalty. *Green Teacher*, (60), 10–17.

Huss, J., & Baker, C. (2010). The farmer in the lab. *Science and Children*, *47*(6), 40–43.

Johnson, G. B. (2018). *The Living World*. New York, NY: McGraw-Hill Education.

Johnson, R. B., & Onwuegbuzie, A. J. (2004). Mixed methods research: A research paradigm whose time has come. *Educational Researcher*, *33*(7), 14–26.

Kellert, S. R. (1993). Values and perceptions of invertebrates. *Conservation Biology*, *7*(4), 845–855.

Killermann, W. (1998). Research into biology teaching methods. *Journal of Biological Education*, *33*(1), 4–9. https://doi.org/10.1080/00219266.1998.9655628

Lamarre, G. P. A., Juin, Y., Lapied, E., Gall, P. L., & Nakamura, A. (2018). Using field-based entomological research to promote awareness about forest ecosystem conservation. *Nature Conservation*, *29*, 39–56. https://doi.org/10.3897/natureconservation.29.26876

Leandro, C., & Jay-Robert, P. (2019). Perceptions and representations of animal diversity: Where did the insects go? *Biological Conservation*, *237*, 400–408. https://doi.org/10.1016/j.biocon.2019.07.031

Lederman, N. G. (2003). Scientific inquiry and nature of science as a meaningful context for learning in science. In *Science literacy for the twenty-first century* (pp. 85–96). Amherst, N.Y: Prometheus Books.

Lockwood, J. A. (2013). *The infested mind: Why humans fear, loathe, and love insects*. New York, NY: Oxford University Press.

Loucks-Horsley, S. (2010). *Designing professional development for teachers of science and mathematics*. Thousand Oaks, Calif: Corwin Press.

Matthews, R. W., Flage, L. R., and, & Matthews, J. R. (1997). Insects as teaching tools in primary and secondary education. *Annual Review of Entomology*, *42*(1), 269–289. https://doi.org/10.1146/annurev.ento.42.1.269

Merriam, S. B. (2009). *Qualitative research: A guide to design and implementation*. San Francisco, CA: John Wiley & Sons.

Miller, J. S., & Naples, V. L. (2002). Forensic entomology for the laboratory-based biology classroom. *The American Biology Teacher*, *64*(2), 136–142. https://doi.org/10.1662/0002-7685(2002)064[0136:FEFTLB]2.0.CO;2

National Academies of Sciences, Engineering, and Medicine. (2016). *Science Teachers' Learning: Enhancing Opportunities, Creating Supportive Contexts*. Retrieved from https://www.nap.edu/catalog/21836/science-teachers-learning-enhancing-opportunities-creating-supportive-contexts

National Research Council. (1996). *National science education standards: Observe, interact, change, learn*. Washington, DC: National Academy Press.

National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Washington, D.C: The National Academies Press.

Newell, S. J. (1994). Occurrence of goldenrod galls: Study of insect ovipositing behavior. *The American Biology Teacher*, *56*(1), 51–54. https://doi.org/10.2307/4449743

NGSS Hub. (n.d.). Retrieved October 8, 2019, from https://ngss.nsta.org/About.aspx

NGSS Lead States. (2013). *Next Generation Science Standards: For States, By States*. Retrieved from http://www.nap.edu/openbook.php?record_id=18290&page=R16

NGSS Lesson Screener. (n.d.). Retrieved October 14, 2019, from https://www.nextgenscience.org/NGSSLessonScreener

NSTA Overview. (n.d.). Retrieved October 15, 2019, from https://www.nsta.org/about/overview.aspx

Onwuegbuzie, A. J., & Leech, N. L. (2005). On becoming a pragmatic researcher: The importance of combining quantitative and qualitative research methodologies. *International Journal of Social Research Methodology, 8*(5), 375–387.

Pearson, G. A., Skinner, K. M., & Hoback, W. W. (2007). Rearing the Masses: Defining Competencies for Entomological Literacy. *American Entomologist*, *53*(4), 216–223.

Plano Clark, V. L., & Ivankova, N. V. (2015). *Mixed methods research: A guide to the field*. Thousand Oaks, CA: Sage Publications.

Powell, J. C., & Anderson, R. D. (2002). Changing teachers' practice: Curriculum materials and science education reform in the USA. *Studies in Science Education*, *37*(1), 107–135. https://doi.org/10.1080/03057260208560179

Prokop, P., Prokop, M., & Tunnicliffe, S. D. (2008). Effects of keeping animals as pets on children's concepts of vertebrates and invertebrates. *International Journal of Science Education*, *30*(4), 431–449.

Prokop, P., & Tunnicliffe, S. D. (2008). "Disgusting" animals: Primary school children's attitudes and myths of bats and spiders. *EURASIA Journal of Mathematics, Science & Technology Education*, *4*(2), 87–97.

Prokop, P., Usak, M., Erdogan, M., Fancovicova, J., & Bahar, M. (2011). Slovakian and Turkish Students' Fear, Disgust and Perceived Danger of Invertebrates. *Hacettepe University Journal of Education*, *40*, 344–352. Retrieved from ERIC. (898324269; EJ936732)

Radavich, R. M. (2019). Entomology education for the visually impaired. *American Entomologist*, *65*(3), 164–167. https://doi.org/10.1093/ae/tmz051

Richardson, M. L. (2010). Publishing scientific outreach materials in educational and social science journals. *American Entomologist*, *56*(1), 11–13.

Richardson, M. L., & Hari, J. (2008). Teaching students about biodiversity by studying the correlation between plants & arthropods. *American Biology Teacher*, *70*(4), 217–220.

Richardson, M. L., & Hari, J. (2009). Building Ecological Complexity in the Classroom Using Pea Aphids & Components of Their Community. *American Biology Teacher*, *71*(5), 286–290. Retrieved from ERIC. (61832374; EJ863740)

Sammet, R., & Dreesmann, D. (2017). What do secondary students really learn during investigations with living animals? Parameters for effective learning with social insects. *Journal of Biological Education*, *51*(1), 26–43. https://doi.org/10.1080/00219266.2016.1150873

Sammet, R., Kutta, A.-M., & Dreesmann, D. (2015). Hands-on or video-based learning with ANTicipation? A comparative approach to identifying student motivation and learning enjoyment during a lesson about ants. *Journal of Biological Education*, *49*(4), 420–440.

Schwagmeyer, P. L., & Strickler, S. A. (2011). Teaching principles of experimental design while testing optimal foraging theory. *American Biology Teacher*, *73*(4), 238–241. https://doi.org/10.1525/abt.2011.73.4.1

Shaffer, J. J., Warner, K. J., & Hoback, W. W. (2007). Filthy flies? Experiments to test flies as vectors of bacterial disease. *American Biology Teacher*, *69*(2), 28–31.

Shepardson, D. P. (1997). Of butterflies and beetles: First graders' ways of seeing and talking about insect life cycles. *Journal of Research in Science Teaching*, *34*(9), 873–889. https://doi.org/10.1002/(SICI)1098-2736(199711)34:9<873::AID-TEA3>3.0.CO;2-R

Shepardson, D. P. (2002). Bugs, butterflies, and spiders: Children's understandings about insects. *International Journal of Science Education*, *24*(6), 627–643. Retrieved from ERIC. (62203347; EJ652727)

Shipley, N. J., & Bixler, R. D. (2017). Beautiful bugs, bothersome bugs, and FUN bugs: Examining human interactions with insects and other arthropods. *Anthrozoös, 30*(3), 357–372. https://doi.org/10.1080/08927936.2017.1335083

Snaddon, J. L., & Turner, E. C. (2007). A child's eye view of the insect world: Perceptions of insect diversity. *Environmental Conservation*, *34*(1), 33–35.

Snaddon, J. L., Turner, E. C., & Foster, W. A. (2008). Children's perceptions of rainforest biodiversity: Which animals have the lion's share of environmental awareness? *PLOS ONE*, *3*(7), e2579. https://doi.org/10.1371/journal.pone.0002579

Terry, M. (2005). Art & evolution. *Science Teacher*, *72*(1), 22–25.

The World Conservation Union. (2014). *IUCN Red List of Threatened Species 2014.3. Summary Statistics for Globally Threatened Species. Table 1: Numbers of Threatened Species by Major Groups of Organisms (1996–2014)*. Retrieved from https://www.iucnredlist.org/en

Travis, H. (2003). Pheromone caterpillar trails: An easy lab exercise for the classroom. *American Biology Teacher*, *65*(6), 456–461.

Triplehorn, C. A., Johnson, N. F., & Borror, D. J. (2005). *Borror and DeLong's introduction to the study of insects.* (7th ed.). Belmont, CA: Thomson, Brooks/Cole.

U.S. Department of Education, National Center for Education Statistics. (2017). Table 105.40. Number of teachers in elementary and secondary schools, and faculty in degree-granting postsecondary institutions, by control of institution: Selected years, fall 1970 through fall 2027. In U.S. Department of Education, National Center for Education Statistics (Series Ed.), *Digest of Education Statistics* (p. 56). Retrieved from https://nces.ed.gov/programs/digest/d17/tables/dt17_105.40.asp

U.S. Department of Education, National Center for Educational Statistics. (2015a). Table 105.50. Number of educational institutions, by level and control of institution: Selected years, 1980-81 through 2013-14. In U.S. Department of Education, National Center for Educational Statistics (Series Ed.), *Digest of Education Statistics* (p. 62). Retrieved from https://nces.ed.gov/programs/digest/d15/tables/dt15_105.50.asp

U.S. Department of Education, National Center for Educational Statistics. (2015b). Table 209.50. Percentage of public school teachers of grades 9 through 12, by field of main teaching assignment and selected demographic and educational characteristics: 2011-12. In U.S. Department of Education, National Center for Educational Statistics (Series Ed.), *Digest of Education Statistics* (p. 158). Retrieved from https://nces.ed.gov/programs/digest/d15/tables/dt15_209.50.asp

Van Hoeck, K. (2010). Using brassica butterflies as a model organism for AP Biology Lab 11. *The American Biology Teacher*, *72*(6), 361–364.

Wagler, R. (2010). The association between preservice elementary teacher animal attitude and likelihood of animal incorporation in future science curriculum. *International Journal of Environmental and Science Education*, *5*(3), 353–375.

Wagler, R. (2017). *Adventures With Arthropods: Eco-Friendly Lessons for Middle School*. Arlington, VA: National Science Teachers Association - NSTA Press.

Wagler, R., & Moseley, C. (2005). Cockroaches in the classroom. *Science Scope*, *28*(6), 34–37.

Wagler, R., & Wagler, A. (2011). Arthropods: Attitude and incorporation in preservice elementary teachers. *International Journal of Environmental & Science Education*, *6*(3).

Wagler, R., & Wagler, A. (2012). External insect morphology: A negative factor in attitudes toward insects and likelihood of incorporation in future science education settings. *International Journal of Environmental & Science Education*, *7*(2).

Wagler, R., & Wagler, A. (2013). Knowledge of arthropod carnivory and herbivory: Factors influencing preservice elementary teacher's attitudes and beliefs toward arthropods. *International Journal of Environmental and Science Education*, *8*(2), 303–318.

Wallace, J., & Louden, W. (1998). Curriculum change in science: Riding the waves of reform. *International Handbook of Science Education*, *1*, 471–485.

Welcome | Lesson Hive. (n.d.). Retrieved October 9, 2019, from https://lessonhive.org/

White, B. T. (2012). The virtual genetics lab II: Improvements to a freely available software simulation of genetics. *The American Biology Teacher*, *74*(5), 336–337. https://doi.org/10.1525/abt.2012.74.5.9

White, H. (2009). Going buggy. *SchoolArts: The Art Education Magazine for Teachers*, *108*(9), 44.

Wilson, E. O. (1987). The little things that run the world (the importance and conservation of invertebrates). *Conservation Biology*, *1*(4), 344–346.

Wilson, S. M. (2013). Professional development for science teachers. *Science*, *340*(6130), 310–313. https://doi.org/10.1126/science.1230725

APPENDICES

Appendix A: Quantitative Phase Informed Consent

Research Participant Informed Consent Form
Insect Incorporation in High School Biology Classrooms (IRB#20150415217 EX)

Purpose of Research: The purpose of this research is to characterize the current state of entomology education in high school biology classrooms, identify barriers to incorporation, and identify resources, tools, or supplies that would support future incorporation. You are invited to participate in this research if you are 19 years of age or older and currently teaching high school biology in the United States.

Specific Procedures to be Used: You will be asked to answer closed- and open-ended questions about your experiences incorporating insects in a high school biology classroom. You will be asked to provide limited demographic information. Providing this information is entirely voluntary.

Duration of Participation: This survey will take approximately 20 minutes to complete. This length may be shorter or longer depending on your experiences and input.

Risks: There are no known risks or discomfort associated with this research.

Benefits: By participating in this research, you will have the opportunity to share your experience and knowledge of how and why insects are incorporated in biology instruction. Findings from this study will be shared with professional scientists, educators, and curriculum developers to inform development of resources and tools to support high school science instruction. You will contribute to understanding of and literature in the field of science education.

Incentive: No monetary incentive will be offered for participating in this study.

Freedom to Withdraw: Participation in this study is voluntary. You can refuse to participate or withdraw at any time without harming your relationship with the researchers or the University of Nebraska-Lincoln, or in any other way receive a penalty or loss of benefits to which you are otherwise entitled.

Confidentiality: This survey was developed and implemented using Qualtrics Survey Software. Their privacy policy can be found athttp://www.qualtrics.com/privacy-statement/.No information identifying you to the research results will be published. Your responses will be kept confidential on secure server with password protection. Responses will be destroyed five (5) years after completion of the study. Results from this study may be published in scientific journals or presented at scientific meetings but identifying information of participants will not appear in any written report or presentation.

Opportunity to Ask Questions: You may ask any questions concerning this research by contacting Erin Ingram (402-472-8692 or erin.michelle.ingram@gmail.com) or Doug

Golick (402-472-8642 or dgolick2@unl.edu). If you would like to speak to someone else, please call the Research Compliance Services Office at (402) 472-6965 orirb@unl.edu.

Consent: You are voluntarily making a decision whether or not to participate in this research study. By clicking on the "I Agree" button below, you agree that you are 19 years of age or older and consent to participate. For future reference, you should print or save a copy of this consent form for your records.

- ○ I Agree
- ○ I Do Not Agree

Appendix B: Insect Incorporation Survey

Instructions: Please answer all questions as completely and accurately as possible. You may go back at any time to change a previous answer to a question. You may save your progress and return at any time to complete the survey. Simply click on the link (or copy and paste the survey link into your browser) to pick up where you left off.

1. In a typical school year, do you incorporate insects into your classroom in any form? (This includes presentation of or interaction with any media depicting an insect such as a picture, video, audio, text, lecture, discussion, activity, lesson, pinned specimen, live insect, etc.)
   - ○ Yes
   - ○ No

2. Do you use a lesson plan when incorporating insects in any form into your classroom in a typical school year? (These may be developed by yourself, another teacher, school district, professional development workshop, website, textbook, trade book, etc.)
   - ○ Yes (Please indicate source of the lesson plan.) ____________________
   - ○ No

3. Which of the following insects have you incorporated into your classroom in any form in a typical school year? (Please check all that apply.)
   - ☐ Ants
   - ☐ Bees
   - ☐ Beetles (including mealworms, ladybugs, fireflies)
   - ☐ Butterflies (including caterpillars)
   - ☐ Cockroaches
   - ☐ Crickets
   - ☐ Flies (including fruit flies, blow flies, house flies, maggots)
   - ☐ Grasshoppers
   - ☐ Mosquitoes
   - ☐ Moths (including silkworms)
   - ☐ Praying Mantids
   - ☐ Termites
   - ☐ True bugs (including milkweed bugs, cicadas, stink bugs)
   - ☐ Wasps (including WOWbugs)
   - ☐ Other insects (Please specify.) ____________________

4. In a typical school year, how often do you incorporate insects in any form into your classroom teaching?
   - ○ Less than Once a Month
   - ○ Once a Month
   - ○ 2-3 Times a Month
   - ○ Once a Week
   - ○ 2-3 Times a Week

- ○ Daily

5. Would you consider incorporating insects into your classroom in any form in the future?
   - ○ Yes
   - ○ No

6. Are insects used to teach about any of the following entomology topics?

	Yes	No
Ecosystem functioning (insects as food, plant pollination, etc.)	○	○
Ecosystem indicators (biodiversity, habitat or climate change, etc.)	○	○
Scientific practice (experiments, investigation, or inquiry using insects)	○	○
Insect products (insects produce silk, wax, lacquer, honey, etc.)	○	○
Human health (malaria, yellow fever, dengue fever, plague, etc.)	○	○
Animal health (irritation or disease by mosquitoes, fleas, or ticks, etc.)	○	○
Agriculture and food supply (insect pests, crop pollination, natural enemies, biological control, etc.)	○	○
Decision-making processes (Integrated pest management, risk assessment, pest control, etc.)	○	○
Aesthetic value (art, design in nature, etc.)	○	○

7. Which concepts or topics are supported by teaching about insects in your classroom?

	Yes	No
Cause and Effect	○	○
Patterns	○	○
Systems and System Models	○	○
Stability and Change	○	○
Structure and Function	○	○
Heredity and Inheritance	○	○
Adaptation	○	○
Biodiversity	○	○
Evolution	○	○
Ecosystems	○	○
Other (Please specify.)	○	○

8. Which skills or practices do your students develop by incorporating insects in your classroom?

	Yes	No
Observing	○	○
Asking questions and defining problems	○	○
Developing and using models	○	○
Planning and carrying out investigations	○	○

Analyzing and interpreting data	O	O
Measuring and collecting data	O	O
Constructing explanations and designing solutions	O	O
Engaging in argument from evidence	O	O
Evaluating and communicating information	O	O
Other (Please specify.)	O	O

9. In three sentences, please describe how your students benefit from learning about insects in your classroom.

____
____
____

10. Do you use any live insects or other animals into your classroom in a typical school year? (This may include mammals, birds, reptiles, amphibians, fish, arthropods, annelids, cnidarians, echinoderms, mollusks, etc.)
    - O Yes (Please specify which types of animals are used.) ____________________
    - O No

11. Please indicate if any of the following are barriers to incorporating insects into your classroom.

	Yes	No
Teaching with live insects is not allowed within my school or district.	O	O
Teaching with live insects causes allergies for myself or my students.	O	O
Teaching about insects does not align with state or national science standards.	O	O
Teaching about insects does not fit with the approved curriculum of my school or district.	O	O
Learning about insects does not interest my students.	O	O
Other (Please specify.)	O	O

12. Assuming the following resources were made available to you, please drag and drop to rank them in order from (1) most useful to (6) least useful when considering incorporating insects into your classroom.
    - _______ Live insects available for check out
    - _______ Insect collecting supplies available for check out
    - _______ Lesson plans aligned to national or state standards
    - _______ A guide on caring for insects in the classroom
    - _______ Professional entomologists visiting your classroom
    - _______ A professional development workshop focused on how to use insects in inquiry

13. In three sentences, please describe any tools, supplies, or resources which would best support future insect incorporation in your classroom.

____
____
____

14. Please indicate your level of agreement with the following statements.

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
I am comfortable handling insects.	○	○	○	○	○
I find the appearance of insects appealing.	○	○	○	○	○
I have received adequate training to teach about insects.	○	○	○	○	○
I am confident in my ability to teach about insects.	○	○	○	○	○
I am capable of caring for insects in my classroom.	○	○	○	○	○
I feel the cost of teaching with insects is affordable.	○	○	○	○	○
I have time to teach about insects.	○	○	○	○	○
I feel there are plenty of quality lesson plans involving insects.	○	○	○	○	○

15. In three sentences or less, please explain why you view insects positively or negatively.

____
____
____

Finally, we have some background questions.

16. What is your gender?

- ○ Female
- ○ Male
- ○ Other

17. What is your age?

- ○ 20-29
- ○ 30-39
- ○ 40-49
- ○ 50-59
- ○ 60 or older

18. As of the end of the current school year, how many years have you been teaching science in a formal setting?
    - ○ Participants offered single choice between 1-45

19. Which grade level(s) are you teaching this school year? (Please check all that apply.)
    - ☐ Grade 9
    - ☐ Grade 10
    - ☐ Grade 11
    - ☐ Grade 12
    - ☐ Other ____________________

20. Please indicate which life science courses you have experience in teaching. (Please check all that apply.)
    - ☐ Biology
    - ☐ Environmental Science
    - ☐ Zoology
    - ☐ Anatomy/Physiology
    - ☐ Agriculture Science
    - ☐ Other (Please specify.) ____________________

21. Which college degrees do you hold? (Please select all that apply.)
    - ☐ Associate degree
    - ☐ Bachelor of Arts
    - ☐ Bachelor of Science
    - ☐ Master's Degree in Education
    - ☐ Master's Degree in Science
    - ☐ Doctorate of Education or Ph.D. in Education
    - ☐ Ph.D. in Science
    - ☐ Other (Please indicate degree.) ____________________

22. Please indicate if you have ever participated in any of the following.

	Yes	No
A college-level entomology course	○	○
Professional development involving insects	○	○
Other education experience with insects (Please specify.)	○	○

23. Please provide your school name and location below. This information will be used to determine a rural, town, suburb, or city designation for your school.
    School Name ________________________________
    City ____
    State (2 letter abbreviation) ____________________
    Zip code ____________________________________

24. Please provide your email address if you would be willing to answer brief follow-up questions regarding your experience with insects in science instruction.
    ____

Appendix C: Survey Participants Selected for Follow-Up Interview

Participant Code	Gender	Age	Years of Science Teaching Experience	Insects Used Once a Month or More	5+ Types of Insects Used	4+ Entomology Topics Taught	5+ Science Concepts Taught	5+ Science Practices Taught	College Level Entomology Class	Professional Development with Insects	Other Entomology Education Experience
EI01	F	50-59	25	X	X	X	X	X	Y	N	Y
EI02	F	30-39	8	X	X	X	X	X	Y	N	N
EI03	M	40-49	19	X	X	.	X	X	N	N	N
EI04	M	60-older	8	X	.	X	X	X	Y	Y	Y
EI05	F	40-49	26	X	X	X	X	X	Y	N	Y
EI06	F	50-59	20	X	.	X	X	.	Y	N	Y
EI07	F	50-59	26	.	X	X	.	.	N	N	N
EI08	F	40-49	19	.	.	.	X	X	N	N	N
EI09	F	40-49	20	.	X	X	X	X	N	N	N
EI11	F	30-39	8	.	.	.	.	.	N	N	Y
EI12	M	40-49	21	X	X	X	X	X	Y	Y	Y
EI13	F	50-59	15	.	.	.	.	X	N	N	N
EI15	M	30-39	9	.	X	.	.	X	N	N	Y
EI16	M	50-59	22	X	X	X	X	X	N	N	Y
EI18	M	20-29	5	X	X	.	X	.	Y	N	N
EI19	M	40-49	17	X	X	X	X	X	Y	Y	Y
EI20	F	50-59	23	X	.	.	.	X	Y	Y	Y
EI22	F	30-39	.	.	.	.	.	.	N	N	N

Appendix D: Qualitative Phase Informed Consent

Follow-up Survey Participant Informed Consent Form
Insect Incorporation in High School Biology Classrooms
(IRB#20150415217 EX)

Purpose of Research: The purpose of this research is to characterize the current state of entomology education in high school biology classrooms, identify barriers to incorporation, and identify resources, tools, or supplies that would support future incorporation. You are invited to participate in this research if you are 19 years of age or older and currently teaching high school biology in the United States.

Specific Procedures to be Used: You will be asked to answer open-ended questions about your experiences incorporating insects in a high school biology classroom. Providing this information is entirely voluntary.

Duration of Participation: This interview or web survey will take approximately 30 minutes to complete. This length may be shorter or longer depending on your experiences and input.

Risks: There are no known risks or discomfort associated with this research.

Benefits: By participating in this research, you will have the opportunity to share your experience and knowledge of how and why insects are incorporated in biology instruction. Findings from this study will be shared with professional scientists, educators, and curriculum developers to inform development of resources and tools to support high school science instruction. You will contribute to understanding of and literature in the field of science education.

Incentive: No monetary incentive will be offered for participating in this study.

Freedom to Withdraw: Participation in this study is voluntary. You can refuse to participate or withdraw at any time without harming your relationship with the researchers or the University of Nebraska-Lincoln, or in any other way receive a penalty or loss of benefits to which you are otherwise entitled.

Confidentiality: If you are participating in a telephone interview, responses will be recorded and transcribed at a later date. No identifying information will be attached to your responses. If you are answering questions on the web, this survey was developed and implemented using Qualtrics Survey Software. Their privacy policy can be found at http://www.qualtrics.com/privacy-statement/. No information identifying you to the research results will be published. Your responses will be kept confidential on secure server with password protection or in a locked filing cabinet. Audio recordings will be destroyed after the interview has been transcribed (approximately 90 days). Responses will be destroyed five (5) years after completion of the study. Results from this study may be published in scientific journals or presented at scientific meetings but identifying information of participants will not appear in any written report or presentation.

Opportunity to Ask Questions: You may ask any questions concerning this research by contacting Erin Ingram (402-472-8692 or erin.michelle.ingram@gmail.com) or Doug Golick (402-472-8642 or dgolick2@unl.edu). If you would like to speak to someone else, please call the Research Compliance Services Office at (402) 472-6965 or irb@unl.edu.

Teacher Informed Consent Form
Case study of insects in the life science classroom
(IRB Number: 20170517174 EP)

Purpose of Research: The purpose of this research is to characterize entomology education in high school biology classrooms, identify barriers to and benefits from incorporation, and identify resources, tools, or supplies that would support future incorporation. You are invited to participate in this research if you are 19 years of age or older, currently teaching a high school life science course, and will teach with or about insects or insect-related content during the course of normal classroom instruction.

Specific Procedures to be Used: A video camera will record classroom instruction sessions involving insects or insect-related content. You will be asked to wear a wireless, lavalier (clip-on) microphone to capture audio during lecture, discussion, or interaction with students. Video recordings and associated audio will be stored on a password-protected computer. Only the research team will have access to video recordings. We will collect curriculum resources (lesson plans, activities, etc.) and completed student work associated with your insect-related instruction. We will also conduct pre- and post-instruction student and teacher interviews regarding the process and employ a brief instrument to measure students' attitudes toward insects.

Duration of Participation: Video recordings of your classroom instruction will occur approximately 6-10 times in a single academic year depending on the amount of insect-related content included in your instruction. Recordings will take place during the 2017-2018 or 2018-2019 school years. Setting up the video camera should take no more than 5 minutes at the beginning of each recorded class period. Collection of lesson plans and student work should take no more than 1 hour in total. Teacher interview protocols should take no more than 1 hour in total. In addition, the student survey and interview procedures will last no more than 1 hour in total.

Risks: There are no known risks or discomfort associated with this research.

Benefits: By participating in this research, you will have the opportunity to share your experiences in using insects as part of biology instruction. Findings from this study will be shared with professional scientists, educators, and curriculum developers to inform development of resources and tools to support high school science instruction. You will contribute to understanding of and literature in the field of science education.

Incentive: No monetary incentive will be offered for participating in this study.

Freedom to Withdraw: Participation in this study is voluntary. You can refuse to participate or withdraw at any time without harming your relationship with the researchers or the University of Nebraska-Lincoln, or in any other way receive a penalty or loss of benefits to which you are otherwise entitled.

Confidentiality: Any information obtained during this study that could identify you will be kept strictly confidential. All data will be coded. Only members of the research team will have access to the coded data. The results obtained from this study may be published in scientific journals or presented at scientific meetings, but the no identifying information will be reported that would identify students, teachers, classrooms or schools. Video recordings will be destroyed three years after completion of the study.

Opportunity to Ask Questions: You may ask any questions concerning this research by contacting Erin Ingram (402-472-8692 or erin.michelle.ingram@gmail.com) or Doug Golick (402-472-8642 or dgolick2@unl.edu). If you would like to speak to someone else, please call the Research Compliance Services Office at (402) 472-6965 or irb@unl.edu. You are voluntarily making a decision whether or not to participate in this research study. Your signature certifies that you have decided to participate having read and understood the information presented. You will be given a copy of this consent form to keep.
The University of Nebraska-Lincoln wants to know about your research experience. This 14 question, multiple-choice survey is anonymous; however, you can provide your contact information if you want someone to follow-up with you. This survey should be completed after your participation in this research. Please complete this optional online survey at: http://bit.ly/UNLresearchfeedback.

Printed Name of Teacher ____________________________ Date _________________

Signature of
Teacher____

Signature of
Investigator____

Student Informed Assent Form
Case study of insects in the life science classroom
(IRB Number: 20170517174 EP)

You are being invited to participate in a research study being conducted by investigators at the University of Nebraska-Lincoln. As part of this study, we will be conducting classroom observations of high school biology instruction involving insects or insect-related instructional materials. We will be examining student discussion, lab activities, behaviors, and interactions as well as collecting classroom work, conducting student interviews about your experiences, and using a survey to measure your attitudes toward insects. This project will examine the impact of insect-related instruction on student attitudes and learning. Although we would like to include all students in your science classroom, you can request that your data not be used for this research. Please read the following description and decide if you want to request that you not participate. On the reverse side of this letter, you will find information about how to request that your data not be included in this research.

As part of this project, video recordings will be made of insect-related biology instruction. Video recording will be made using a video camera placed at the back of the classroom. Every effort will be made to record only the back of students' heads rather than their faces. Your teacher will wear a clip-on microphone to record audio of lectures, discussions, or student interactions. All student information (e.g., names) obtained by researchers will remain confidential. Pseudonyms will be used in any presentation, publication, or reporting of this data to protect the identity and privacy of individuals. On the reverse side of this letter is a list of frequently asked questions which should help to answer any questions you may have regarding this study. In you have any additional questions or comments about this project, please do not hesitate to call (402) 472-8692 and ask for Erin Ingram. You can also write us at the address on this letterhead or send an email to erin.michelle.ingram@gmail.com

Sincerely,

Erin Ingram
Graduate Research Assistant
University of Nebraska, Department of Entomology

Frequently Asked Questions
The purpose of this study is to examine how and why entomological subject matter is presented in high school science classrooms. This study will examine the process of insect incorporation at the secondary level, gather data on student understanding and attitudes associated with insects, identify barriers to teaching with and/or about insects, and identify potential ways to support future entomology incorporation in science classrooms.

Are there any risks if I participate?
There are no known risks or discomforts associated with this research, as all insect-related lessons are part of normal instructional practices. In the event of problems resulting from participation in the study, you may contact Erin Ingram, Graduate Research Assistant, for assistance or referral at 402-472-8692 or erin.michelle.ingram@gmail.com.

Are there any benefits?
Being in this study will not have direct benefits to you, however, your participation will help researchers and teachers to better understand student outcomes from insect-related lessons and aid in the development of tools or resources for teachers which may improve future science instruction.

How do I know my information is confidential?
Any information obtained during this study that could identify you will be kept strictly confidential. The video recordings will be stored on a password-protected computer at the University of Nebraska-Lincoln. Any identifiable information from the video recordings will be coded with a pseudonym prior to presentation or publication to protect student identity. The results obtained from this study may be published in scientific journals or presented at scientific meetings, but the data will be reported without information that would identify students, teachers, classrooms or schools.

If I still have questions that are not answered here, who can I contact?
Investigators on this project include Dr. Doug Golick and PhD student, Erin Ingram. You may ask questions about this research and have those questions answered before, during, or after the study by contacting the lead Principal Investigator Erin Ingram at (402) 472-8692 or erin.michelle.ingram@gmail.com. If you have questions about your rights as a research participant that have not been answered by the investigators, or to report any concerns, you may contact the University of Nebraska-Lincoln Institutional Review Board at (402) 472-6965.

Freedom to withdraw:
You are free to decide that you do not want your data to be included in this study and to withdraw at any time without adversely affecting your relationship with the investigators, your school, your teacher, or the University of Nebraska-Lincoln. Your decision will not result in any loss of benefits to which you are otherwise entitled. While we like to involve all eligible students in this study, you are free to decide not to have your data included in

the study or to withdraw at any time. You do not need to sign or return this letter. It is yours to keep.

Assent:
To request that your data not be included in this study, you may call or send a written note to your science teacher, the school, or Erin Ingram at 103 Entomology Hall, Lincoln, NE 68583.

Student Informed Assent Form
Case study of insects in the life science classroom
(IRB Number: 20170517174 EP)

We are inviting you to participate in this study because we would like to understand how and why insects are used in high school science classrooms.

This research will involve video recording of your normal classroom instruction involving insects or insect-related content. It will also include collecting your classroom work, participating in a student interview about your experiences, and taking a survey on your attitudes toward insects. Being in this study will not have direct benefits to you, however, your participation will help researchers and teachers to better understand student outcomes from insect-related lessons and aid in the development of tools or resources for teachers which may improve future science instruction.

There are no known risks or discomfort associated with this research. The camera used for video recording will be placed at the back of the classroom typically recording the back of students' heads but not their faces. Your teacher will wear a microphone to record audio from lectures, discussions, or other interactions with students during the lesson. Any recorded audio will be strictly confidential. Video recordings will be coded and stored on a password-protected computer accessible only to the investigators. We may publish a summary of responses in an academic or trade journal or present a summary at a scientific meeting, however, your identity and responses would be entirely confidential.

We will also notify your parent or guardian of this study. Please feel free to consult your parent or guardian before you decide whether or not to participate.

If you have questions at any time, you can contact Erin Ingram (402-472-8692 or erin.michelle.ingram@gmail.com) or Dr. Doug Golick (402-472-8642 or dgolick2@unl.edu). If you would like to speak to someone else outside the research team, please call the Research Compliance Services Office at (402) 472-6965 or irb@unl.edu. You are voluntarily making a decision whether or not to participate in this research study. Your signature certifies that you have decided to participate having read and understood the information presented. You will be given a copy of this consent form to keep.

Printed Name of Student _________________________ Date ________________

Signature of Student

____

Signature of Investigator

____

Parent Notification Letter
Case study of insects in the life science classroom
(IRB Number: 20170517174 EP)

Dear Parent,
Your child is invited to participate in a research study being conducted by investigators at the University of Nebraska-Lincoln. As part of this study, we will be conducting classroom observations of high school life science instruction involving insects or insect-related instructional materials. We will be examining student discussion, lab activities, behaviors, and interactions and collecting artifacts such as student work to determine the impact of insect-related instruction on student attitudes and learning.

As part of this project, video recordings will be made of insect-related biology instruction. Videos will be recorded using a video camera placed at the back of the classroom. Every effort will be made to record only the back of students' heads rather than their faces. Your child's teacher will wear a clip-on microphone to record audio of lectures, discussions, or student interactions. In addition to recording videos, we will be collecting student work, conducting student interviews, and employing a survey of attitudes toward insects. All student information (e.g., names) obtained by researchers will remain confidential. Pseudonyms will be used in any presentation, publication, or reporting of this data to protect the identity and privacy of individuals.

Additional information is available on the following consent form which should help to answer any questions you may have regarding this study. In you have any further questions or comments about this project, please do not hesitate to call (402) 472-8692 and ask for Erin Ingram. You can also write us at the address on this letterhead or send an email to erin.michelle.ingram@gmail.com

Sincerely,

Erin Ingram
Graduate Researcher
University of Nebraska, Department of Entomology

Parent/Legal Guardian Informed Consent Form
Case study of insects in the life science classroom
(IRB Number: 20170517174 EP)

Purpose:
This research project will examine how and why insect-related subject matter is presented in high school life science classrooms. Your child/legal ward is invited to participate in this study because he/she is part of a high school life science course in which insects or insect-related material will be taught during the course of normal classroom instruction.

Procedures:
This research study asks that your child/ward participate in a pre- and post-instruction survey about their attitude toward insects, have their activities and behaviors video recorded during normal science instruction, have their student work collected and analyzed as data, and potentially provide their understanding and opinions regarding insects during two, semi-structured interviews. Not all students will participate in the two, semi-structured interviews. The survey and interview procedures will last no more than 1 hour in total and will be conducted in the science classroom or in a quiet room at the high school. The video recordings will take place over the course of 6-10 class periods in the science classroom. If you do not wish your child/ward to participate, he/she will not take the pre- or post-instruction survey, will not have their student work collected, and will not be asked to participate in the semi-structured interviews.

Benefits:
There are no direct benefits to them as a research participant; however, the benefits to science and/or society may include that teachers will have access to the overall results to aid in decision-making regarding science classroom and instructional practices. In addition, we hope to inform other researchers and practitioners of the information we learn about tools or resources which may improve future insect incorporation in life science classrooms.

Risks and/or Discomforts:
There are no known risks or discomforts associated with this research.

Confidentiality:
Any information obtained during this study which could identify them will be kept strictly confidential. If student names are made known during the video or audio recording or student work collection process, pseudonyms will be given to all participants to ensure confidentiality.

The survey data, student work, and interview transcripts will be stored in a locked cabinet in the investigator's office and will only be seen by the research team during the study and for 3 years after the study is complete. The video recordings will be stored on a password-protected computer at the University of Nebraska-Lincoln. Any identifiable information from the video recordings will be coded with a pseudonym prior to presentation or publication to protect student identity.

The information obtained in this study may be published in scientific journals or presented at scientific meetings but the data will be reported as group or summarized data. No identifiable data will be published or reported in any presentation.

Opportunity to Ask Questions:
You and your child/legal ward may ask any questions concerning this research and have those questions answered before agreeing to participate in or during the study. You may contact the investigator(s) at the phone numbers below. Please contact the University of Nebraska-Lincoln Institutional Review Board at (402) 472-6965 to voice concerns about the research or if you have any questions about your child's/legal ward's rights as a research participant.

Freedom to Withdraw:
Participation in this study is voluntary. You and your child/legal ward can refuse to participate or withdraw at any time without harming you or your child's and their relationship with the researchers, their science teacher, their school, the University of Nebraska-Lincoln, or in any other way receive a penalty or loss of benefits to which you or they are otherwise entitled. Also, their grades will not be affected by their participation or withdrawal from the research.

Consent, Right to Receive a Copy:
You are voluntarily making a decision whether or not to allow your child/legal ward participate in this research study. Your child/legal ward will also agree to be included within the study by providing assent if they are above the age of seven years old. Your signature certifies that you have decided to allow them to participate having read and understood the information presented. You will be given a copy of this parental/legal guardian consent form to keep.

Participant Feedback Survey:
The University of Nebraska-Lincoln wants to know about you or your child's research experience. This 14 question, multiple-choice survey is anonymous; however, you can provide your contact information if you want someone to follow-up with you. This survey should be completed after your participation in this research. Please complete this

optional online survey at: http://bit.ly/UNLresearchfeedback.

Name of Child to be Included:

____

(Name of Child: Please print)

Name & Signature of Parent/Legal Guardian:

____

(Name of Parent/Legal Guardian: Please print)

______________________________________ ____________________________

(Signature of Parent/Legal Guardian) Date

Name and Phone number of investigator(s)

Erin Ingram, Primary Investigator Office: (402) 472-8692

Dr. Doug Golick, Secondary Investigator Office: (402) 472-8642

Appendix E: Semi-structured Follow-up Teacher Interview Script

Hello. Thank you for your help on this research project to understand how and why insects are being used in U.S. high school biology classrooms. This follow-up interview should take about 30 minutes to complete.

Before we get started, I want to be sure you understand your rights as a participant in the study. An informed consent form was included in our email correspondence, but to clarify, your participation in this study is completely voluntary and you are free to withdraw at any time. If you do not wish to answer a question at any point in the interview, you can let me know that during the interview and I will move on to the next question. Do you understand your rights as a participant?

For the sake of anonymity, I won't be using your name during this interview. Instead, I will be using a code, ______state participant code: EI01, EI02, etc.____. Lastly, I will be recording our interview to ensure the accuracy and clarity of our conversation. Do you consent to participate in this study and agree to be recorded for this interview?

Great. Let's get started.

1. How did you get started teaching about insects in your classroom?
2. What factors made insect incorporation possible?
3. What "big ideas" do you want your students to understand about insects when they have left school?
4. Do you help students connect the impact of insects to their daily lives? If so, how?

Next, I would like you to recall a time when teaching about insects in your classroom was especially effective. Please describe the experience by answering the following questions:

5. How were insects used to support science concepts or practices?
6. Why did you choose to incorporate an insect in this lesson?
7. How did the use of insects help to improve student understanding or engagement?
8. How and why was this particular lesson so successful?

Now we are going to switch gears a little bit and discuss lesson plans.

9. Where do you go to find quality lesson plans?
10. What elements do you look for in a high quality lesson plan?
11. How would providing you with a lesson plan help you to incorporate insects into instruction?

Appendix F: In-depth Semi-Structured Teacher Interview Script

Thank you for agreeing to help me with this project. Our interview should take 20 to 30 minutes. As you know, the purpose of this research study is to examine how and why insects and insect-related subject matter are presented in high school science classrooms. With your help, I am gathering data to describe the process of insect incorporation in your classroom, identify barriers or challenges to insect incorporation, and identify potential ways to support future insect incorporation in science classrooms.

Before we get started, I want to be sure you understand your rights as a participant in the study. Your participation in this study is voluntary and you are free to withdraw at any time. If you do not wish to answer a question at any point in the interview, you can let me know during the interview and I will move on to the next question. Lastly, I will be recording our interview to ensure the accuracy and clarity of our conversation. Do you consent to participate in this study and agree to be recorded for this interview?

Unless you have any questions for me, let's get started!

1. Can you tell me a little bit about your approach to teaching science?
2. Can you tell me a little bit about how insects fit into this approach?
3. How did you get started teaching about insects in your classroom?
4. Can you tell me about any formal or informal entomology experiences or training that you have that make it easier to teach with insects or insect-related materials?
5. What factors make insect incorporation possible?
6. What challenges, if any, make it difficult to incorporate insects into your instruction?
7. What purpose do you think insects serve when using them in your life science classroom?
8. What "big ideas" do you want your students to understand about insects when they have completed this unit?
9. How do you want students to be knowledgeable about insects when they have completed this unit? Why?
10. How and why was this particular lesson/unit so successful?
11. How do you feel insects supported the teaching of science concepts?
12. How do you feel insects supported the teaching of science practices?
13. How did the use of insects in this lesson/unit help to improve student understanding or engagement?
14. Why did you choose to incorporate insects or insect-related material in this lesson?
15. What important information or advice would you share with a science teacher who wants to include insects or insect-related materials in their classroom?

Appendix G: Semi-Structured Student Interview Script

1. When I say the word “insect”, what are three words that come to mind?
2. Can you give me a few examples of insects?
3. What are some characteristics of insects?
4. How do you feel about insects?
5. What personal experiences, if any, affect your attitude toward insects?
6. Do you notice insects when you are outside or going for a walk?
7. Do you feel that insects affect your daily life? If so, how?
8. What was the best part of this unit involving insects?
9. What was the worst part of this unit involving insects?
10. What is something you learned about insects specifically in this unit? How does this understanding help you better understand other animals or organisms?
11. Do you feel like you have a better understanding of insects and other arthropods after participating in this class? Can you provide an example or evidence of your learning?
12. Do you feel like you have a greater appreciation for insects and other arthropods after participating in this class?
13. Is there anything else that you want to share with me about what you learned or how you feel about insects after participating in this class?

Appendix H: Qualitative themes grounded in data

Research Question	Code Group	Code	Grounded
1	Educational Outcomes	1- Addressing misconceptions	23
	Educational Outcomes	1- Being memorable	7
	Educational Outcomes	1- Connecting classroom to the real world	63
	Educational Outcomes	1- Developing students' critical thinking skills	21
	Educational Outcomes	1- Engaging in science practices	65
	Educational Outcomes	1- Illustrating key science ideas with insect examples or models	57
	Emotional Outcomes	1- Student empathy/concern/care for insects	11
	Emotional Outcomes	1- Student enjoyment/excitement	55
	Emotional Outcomes	1- Student overcoming fear/disgust	14
	Emotional Outcomes	1- Teacher enjoyment	12
2	Facilitators and Barriers	2- Access to necessary entomology resources	51
	Facilitators and Barriers	2- Insect characteristics	26
	Facilitators and Barriers	2- Impact of institutional or policy directives	11
	Facilitators and Barriers	2- Teachers' prior entomology experiences	34
	Facilitators and Barriers	2- Availability of instructional time	6
3	Lesson Plan Recommendations	3- Provides new or updated entomology content	16
	Lesson Plan Recommendations	3- Supports student learning	45
	Lesson Plan Recommendations	3- Supports teacher facilitation	19
	Lesson Plan Recommendations	3- Works within constraints	29