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Exploring undergraduate students’ topic interest, topic knowledge, and attitudes regarding harmful algal blooms

Alia N. Thompson

Syracuse University

ABSTRACT

Harmful algal blooms (HABs) are a growing concern in the US and abroad. Persistent misconceptions regarding HABs can increase the negative effects of bloom events by decreasing the effectiveness of communication efforts and impeding mitigation, monitoring, and recovery efforts. Addressing the misconceptions of diverse audiences has remained a prominent barrier in effectively communicating HABs and working towards HABs literacy. Undergraduates are a target audience for HABs outreach. However, there is a lack of information about the antecedents that influence their misconceptions related to HABs and efforts to address their misconceptions may not be as successful or engaging as they could be.

This study looked at undergraduate students' topic interest, topic knowledge, and attitudes regarding HABs. The sample population for this study consisted of n=212 participants; n=50 were science majors and n=157 were non-science majors. Quantitative data were gathered from participants' survey responses. Qualitative data were gathered from individual semi-structured interviews, n=6. The quantitative data were the main focus of this study and were statistically analyzed using ANOVA and multiple regression. Also, the interaction between topic interest and topic knowledge was graphed with relation to attitudes towards HABs. The qualitative data represented a smaller portion of this study's focus. Interview responses were grouped by participant and question, then summarized based on learner characteristics, prior knowledge, motivation, and preference for HABs resource design.

In general, participant topic interest and topic knowledge scores indicated that they had generally low interest in HABs, and low conceptual and factual knowledge related to HABs. Science majors had slightly higher interest and knowledge levels than did non-science majors.

The findings of this study indicated that college major did not have a statistically significant effect on the study populations' attitudes towards HABs.

Topic knowledge was a better predictor of risk attitudes. The relationship between topic interest and risk depended on students' level of topic knowledge and a stronger relationship was observed at lower, rather than at higher, levels of topic knowledge. Participants' topic interest and topic knowledge significantly interacted to predict risk attitudes.

Both topic interest and topic knowledge were predictors of cause and effect attitudes; however, topic interest was a stronger predictor. The relationship between topic interest and attitudes towards HABs causes and effects depended only slightly on students' level of topic knowledge, with a stronger relationship emerging between topic interest and cause and effect at lower, rather than at higher, levels of topic knowledge.

Participants who had heard of HABs reported learning about the topic from: (a) news or websites; (b) high school biology; (c) living in an area prone to HABs or; (d) experiencing a bloom event while traveling. Participants reported their sources of motivation for engaging with the topic were related to: (a) a belief that research is important; (b) interest in other environmental issues; (c) social context; (d) self-efficacy, and; (e) incentives. They suggested that to best engage undergraduates in HABs, the following strategies should be used: (a) social media; (b) human stories and data; (c) text; (d) case studies, and; (e) classroom instruction that teaches students how to take action on the topic. Given participant suggestions, some examples of appropriate instructional resources include, refutational texts, socio-biological case-based learning, and a socio-scientific issues framework.

HABs need to be framed in a way in which students can clearly see that it is a topic that is personally relevant to them and educators need to specifically address misconceptions that may contribute to inaccurate beliefs about the risks of HABs. Given the negative consequences related to bloom events and the fact that there is no one solution to HABs issues and no known solution to keeping HABs from occurring, seeking to foster functional HABs literacy is the most viable solution for managing HABs issues now and in the future.

Keywords: Harmful algal blooms, CRKM, Misconceptions, SSI

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and attitudes regarding harmful algal blooms

By

Alia Nicole Thompson

B.A., University of Hawaii, Manoa, 2008
M.Ed., University of Hawaii, Manoa, 2013

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Dedication

ʻŌlelo noʻeau #325 -E kuhikuhi pono i na au iki a me na au nui o ka ʻike (Pukui, 1983).

Humbly dedicated to my family, my students, and my teachers

Mahalo Nui Loa

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CHAPTER I: INTRODUCTION

A harmful algal bloom is an event that occurs when colonies of algae or bacteria grow out of control, causing harm, by production of toxins that spread through the ecosystem and/or a variety of environmental impacts that arise from having excessive algal populations (at least one million algae per liter of seawater in the US) (Central and Northern California Ocean Observing System (CeNCOOS), n.d.) HAB species are diverse, research is ongoing and evolving, and bloom events are a global problem with local and regional causes and impacts (The Harmful Algal Research and Response: A National Environmental Science Strategy 2005-2015 (HARRNESS), 2005).

Although the National Science and Technology Council Subcommittee on Ocean Science and Technology (NSTC) (2016) suggested the use of evidence-based strategies in communicating HABs, including education and outreach efforts, there is little other guidance provided. Communicating HABs is often then facilitated via media outlets. Despite the diverse causes and effects of HAB events, a trend in media coverage is the tendency to primarily cover HABs as an environmental issue, focusing on the negative environmental outcomes (Li et al., 2013). The situation is further complicated as methods of communicating science in general are frequently changing and most HAB studies are written for scientists, not the public (Hardy et al., 2016; Smith et al., 2014).

The broader goals of HABs education and outreach seek to facilitate what is known as functional science literacy in citizens, to influence their beliefs and behaviors such that the impact of bloom events can be mitigated and recovery from those impacts is accelerated (Bauer et al., 2010). Functional scientific literacy can generally be described as, “the science knowledge needed by individuals to enable them to function effectively in specific settings,” (Ryder, J., 2001, p. 3). Identifying and addressing misconceptions regarding HABs is critical to improving education and outreach efforts and working towards functional HABs scientific literacy (Bauer et al., 2010; Berdalet et al., 2016; Smith et al., 2014). A misconception, for the purpose of this study, is defined as “an understanding that is different from what is scientifically accepted,” (National Research Council, 2012 as cited in Heddy et al., 2017, p. 514).

The Human Dimensions Research Strategy report refers to the HABs education and outreach efforts discussed above and states, “The success of education and outreach efforts for these outcomes relies on tailoring programs to deliver accessible information to, and harness the participation of diverse sectors…,” (Bauer, 2006, p. 42). Higher education students and educators are examples of a target audience that is listed in the HABs education and outreach initiatives because they represent a large diverse pool of future voters, policy makers, and consumers (Bauer, 2006). Science education provides an appropriate space to communicate HABs. Prior research has shown that personal, work-place, and community decisions are affected by the extent of scientific literacy an individual develops in K-12 and postsecondary education (Driver et al., 1996; McComas et al., 1998). The overriding target for science teaching as an aspect of relevant education is seen as responsible citizenry and is based on enhancing scientific and technological literacy (Holbrook & Rannikmae, 2007). Higher education is one of the last opportunities to provide effective opportunities for high levels of cognitive engagement with HABs issues before the individual goes on to the workforce or those who already are in the workforce.

Prior research has shown that there are important differences between groups of undergraduate students. For example, Cotner, Thompson, and Wright (2017) found that non-STEM majors are more likely to have misconceptions about the nature of science but that they do have some understanding of how science works, as compared to biology majors. The authors also found that non-STEM majors were more likely than biology majors to be diverse in regard to their prior knowledge, perceptions, backgrounds, and skills and were less likely to see science topics as personally relevant. However, when looking at the HABs literature, Kirkpatrick et al. (2014) utilized a survey given to residences and tourists and found overall knowledge and attitudes about Florida red tide events did not differ by age, gender, or education level. Undergraduates represent a unique subgroup that should be considered in efforts to better communicate HABs because they come from different backgrounds with varying degrees of interest and knowledge in science topics. Investigating differences that might exist between groups will provide insight into whether there is a need for tailoring programs for this diverse sector based on whether someone is a science or non-science major.

HABs researchers have cited that in order to achieve the goals of communicating effectively and work towards functional HABs scientific literacy (i.e. accurate knowledge, attitudes, and perceptions towards HABs), we must first have insight into an audience's topic knowledge, attitudes, and beliefs towards HABs (Bauer et al., 2010). Information that is necessary to assess an issue and arrive at a reasoned attitude is known as topic knowledge (Petty & Briñol, 2012; Petty & Wegener, 1999). Attitude is described in terms of simple object evaluation; whereby a positive or negative evaluation of an object, person, idea, or event leads to a response or belief that lies somewhere on a scale from favorable to unfavorable (Eagly &

Chaiken, 1993; Heddy et al., 2017). Absent from the researchers' recommendations is the consideration of an audience's level of interest in HABs. The motivation or will to engage in a specific topic denotes the level of an individual's topic interest (Schunk et al., 2014). Interest has been shown to be an indicator of motivation, influence learning (Zeidler & Nichols, 2009), and attitudes towards scientific issues (Gauchat, 2012). Interest was also demonstrated by Gauchat (2012) to have an influence on the formation of people's attitudes towards scientific issues.

Previous research has shown that depending on the scientific issue, the interaction between the variables attitude, interest and knowledge varied in significant ways, and has been important in addressing misconceptions and fostering conceptual change related to those topics (Bråten, Strømsø, & Vidal-Abarca, 2009; Heddy, Danielson, Sinatra, & Graham, 2017; Stenseth, Bråten, & Strømsø, 2016). The study by Bråten et al (2009), regarding climate change, compared and contrasted the topic interest, topic knowledge, and attitudes between undergraduates from Norway who were enrolled in an introductory educational science course and from Spain who were enrolled in an introductory psychology course. Their study found that topic interest in climate change was a better predictor of beliefs across the two cultures than was topic knowledge. The Norwegian undergraduates had higher topic knowledge but lower topic interest scores than Spanish undergraduates. Researchers stated that cultural context was likely a factor in why the two groups differed; climate change was more of a prominent topic of discussion in Norway at the time. So presumably, Norwegian students may have higher topic knowledge but because it is discussed more, may not be as interested.

Stenseth et al (2016) compared and contrasted the topic interest, topic knowledge, and attitudes of high school students in two different countries, Norway and Spain, with relation to climate change and nuclear power. Attitudes towards climate change were shown to become more positive as interest level increased despite the level of knowledge (Stenseth et al., 2016). However, attitudes towards the risk of nuclear power become more negative as highly knowledgeable people become more interested in the topic (Stenseth et al., 2016). The opposite is seen for those who have low interest and knowledge of the subject; as interest increased attitudes became more positive towards the risks associated with nuclear power (Stenseth et al., 2016). All three variables have been shown to have the potential to be antecedents that may influence misconceptions and provide useful information for structuring opportunities for conceptual change to occur.

The goal of conceptual change is to move individuals from their misconception(s) to the accepted scientific perspectives (Heddy et al., 2017). Conceptual change is therefore often a necessary part of working towards functional scientific literacy. Revising misconceptions or updating inaccurate knowledge is a learning process known as conceptual change. It is described as a form of knowledge revision that includes modifying emergent attitudes (Kendeou et al., 2014). There are numerous reasons why misconceptions related to scientific issues are difficult to change. An individual could be unprepared to change their misconceptions because of gaps in knowledge, not finding the topic personally relevant, or the topic is perceived as not comprehensive, coherent, compelling, or plausible.

Problem Statement

Algae species that contribute to HABs are diverse (NOAA, 2016). Certain algae species will sometimes produce toxins, which once the toxin reaches a certain concentration becomes harmful (NOAA, 2016). However not all species of algae produce a toxin, not all blooms produce enough toxins to be considered harmful, and the effects of toxins may not be immediate (NOAA, 2016). Blooms can be visible producing a wide range of colors, blooms can also be colorless giving little indication of their presence (NOAA, 2016). Foam, scum, or mats on the water surface can also be indications of a HAB (Centers for Disease Control and Prevention (CDC), 2018). HAB species are diverse, research is ongoing and evolving, and bloom events are a global problem with local and regional causes and impacts (HARRNESS, 2005).

Some bloom events are naturally occurring, and some are encouraged and exacerbated by human activity (Falk, Darby, & Kempton, 2000). Although the scientific community has not reached a consensus about the causes of HAB events, as they can vary greatly, excess nutrients, poor water circulation, the abundance of sunlight, and warm temperatures are often cited as contributing factors (CDC, 2018; Falk, Darby, & Kempton, 2000; NOAA, 2016). There is no consensus globally on the threshold limits for identifying blooms based on algal toxin or biomass (Smayda, 1997). The distinguishing factor between harmful and non-harmful is often based on the severity of bloom impacts (Smayda, 1997). Bloom events can occur for several days or last for several months (EGLE, 2019). HABs are not usually labeled as such until the impacts of an event are already felt (Smayda, 1997). The magnitude of bloom events depends on location and environment, the type and concentration of algae, and the type and concentration of toxins (if and when they are present) (Smayda, 1997). The results of which can have an equally broad range of effects (NOAA, 2016; Smayda, 1997).

HAB events can negatively affect organisms, the environment, and humans alike (Hoagland et al., 2014; Landsberg, 2002; Smayda, 1997). For example, humans can be exposed to HABs through inhaling airborne toxins, swimming in or drinking contaminated water, and ingesting toxic shellfish (National Institute of Environmental Health Services (NIEHS), 2018). The human health impacts range depending on the toxin and consumption level; exposure to domoic acid from low to high levels, for example, can cause vomiting, diarrhea, confusion, seizures, permanent and short term memory loss, or death (NIEHS, 2018). Other negative consequences of HABs include; clogging of fish gills, boats and desalination filters, hypoxia and fish kills, marine mammal strandings, product and profit loss by the seafood industry, and a decline in tourism during bloom events (Borbor-Córdova et al., 2018; Hoagland et al., 2014; Landsberg, 2002; NOAA, 2016; Smayda, 1997).

A study by Kirkpatrick, Kohler, Byrne, and Studts (2014) found that despite deliberate education and outreach efforts from 2010 to 2015 to address misconceptions related to the risks associated with a type of HAB events, "Florida Red Tides", there was no significant improvement seen in changing public misconceptions towards HABs. Other studies evaluating the effectiveness of HABs education and outreach efforts have reported similar results (Hardy et al, 2016; Smith, Blanchard, & Bargu, 2014).

Research conducted by Nierenberg et al (2010) used a survey to look at tourist versus residents' knowledge of Florida red tide events, and showed that out of the 100 tourists and 92 residents only one tourist had not heard of a Florida red tide and all residents had heard of the red tide. A subsequent survey conducted by Smith et al. (2014) to understand what fishermen know about freshwater HABs in Louisiana, indicated that all participants had heard of algal blooms but that only 40% had heard of HABs. Both studies found widely inconsistent and incorrect responses across participating groups, likely signifying a substantial lack of knowledge, and the prevalence of misconceptions in the public's knowledge of HABs (Nierenberg et al., 2010; Smith et al., 2014).

Hardy et al. (2016) found that although several states have developed protocols for notifying the public of bloom events, national guidelines for effective communication strategies, alerting the public of HAB presence or HAB health risks are lacking. A reason for the lack of effective communication strategies may be due to the inherent diversity and complexity of HAB events which often have specific local and regional impacts (HARRNESS, 2005).

Persistent misconceptions regarding HABs can act to increase the negative effects felt by bloom events and decrease the effectiveness of communication efforts (Berdalet et al., 2016; Borbor-Córdova et al., 2018; Smith et al., 2014). HAB misconceptions are able to persist because events are complex, involve multiple stakeholders, a variety of risks, causes and effects, require multiple mitigations, and recovery solutions but are not portrayed as such (Li et al., 2013). The relationships between misconceptions about HABs and behaviors that are not supported by evidence often contributes to the tangle of social and political components that are inherent in HABs issues (Wells et al., 2015).

Addressing the misconceptions of different audiences has remained a prominent barrier in effectively communicating HABs and working towards HABs literacy. Undergraduates are identified as a target audience for HABs education and outreach but there is a lack of information about the antecedents that influence misconceptions related to HABs, efforts to address their misconceptions may not be as successful as they could be. To address misconceptions requires knowledge about several factors; among them are an individual's motivation to engage in the topic and their prior knowledge, experiences, and attitudes related to that topic.

Understanding undergraduate students' topic interest, topic knowledge, and attitudes towards HABs is critical should they have misconceptions. This is a problem for communicating HABs effectively as there is little related research to aid educators in tackling the challenge. Although Hardy et al (2016) suggested recommendations for HABs education and outreach, their outreach framework does not focus on students or speak specifically to educators. Their guidelines also do not focus on the underlying factors in changing persistent misconceptions related to HABs. Studies have shown that persistent misconceptions about scientific issues can be changed by leveraging characteristics that relate to both the learner and the topic itself through focused instructional strategies. The general problem is that misconceptions about HABs continue to persist and the barriers to communicating HABs effectively remain. The specific problem is that previous studies have predominantly utilized the knowledge and attitudes of the general public or very small specific groups to inform how HAB misconceptions should be addressed. A knowledge gap exists as to what different groups of undergraduates' levels of topic interest, topic knowledge, and attitudes towards HABs can tell us about how best to address their misconceptions and engage them in the topic. There is a lack of information about the antecedents that influence misconceptions and attitudes related to HABs.

Study Purpose and Research Questions

This mixed-methods QUANTITATIVE and qualitative study had several purposes; (a) to explore possible differences between science majors' and non-science majors' topic interest, topic knowledge, and attitudes towards HABs, (b) to investigate the potential context-specificity of the mechanisms, topic interest, and topic knowledge and the relationships between them that may influence attitudes towards HABs, (c) to gain insight into participants' learner characteristics and recommendations for resource design, and (d) utilize the study results to discuss implications for future HABs education and outreach efforts. The goal of this study was to explore the antecedents that influence misconceptions regarding HABs and use the study results to make implications for educators to implement HABs into their instruction. The cognitive reconstruction of knowledge model (CRKM) provided a guiding framework for discussing the implications of and explaining the study results. The CRKM proposed that the conceptual change process begins by investigating the interaction between learner (prior knowledge, attitudes, beliefs, and motivation) and message characteristics (comprehensibility, plausibility, coherence, and rhetorical structure) (Dole & Sinatra, 1998). The CRKM posited that the likelihood of changing an individual's attitudes and misconceptions is based on the interaction between learner and message characteristics, as well as their level of cognitive engagement on a continuum ranging from high to low.

This study included participants that represented both science and non-science majors from a large major research university in the northeastern US. To explore the study variables and context, QUANTITATIVE data was gathered from 212 survey participants. The survey was administered once in the fall 2019 semester and consisted of topic interest, topic knowledge, and attitude measures. The data were statistically analyzed using ANOVA and multiple regression, and the interaction between topic interest and topic knowledge was graphed with relation to attitudes towards HABs. Qualitative data was gathered from six individually conducted semi-structured interviews and was used to support the QUANTITATIVE analysis which was the main focus of this study. Follow-up interviews were aimed at understanding participants' learner characteristics, prior knowledge and motivation, and their preferences for HABs resource design. Interviews were also conducted in the fall of 2019. Using QUANTITATIVE survey data provided insight into the theory or phenomenon as to why misconceptions towards HABs persist and how to address changing them in undergraduates, while qualitative interview data helped to provide details about the variation in levels of topic interest, topic knowledge, and attitudes.

The study addressed the following research questions:

Quantitative:

1. Are there differences between science majors and non-science majors' topic interest, topic knowledge, and attitude levels regarding HABs?
2. Do undergraduate students' topic interest in and their topic knowledge about harmful algal blooms predict their attitudes towards HABs?
    a. Do undergraduate students' interest in and their knowledge about harmful algal blooms, independently and interactively, predict their attitudes towards the risks associated with HABs?
    b. Do undergraduate students' interest in and their knowledge about harmful algal blooms, independently and interactively, predict their attitudes towards the causes and effects of HABs?

Qualitative:

3. What do interviews with survey respondents reveal about participant learner characteristics and their recommendations for HABs education and outreach resource design?

Significance of the Study

The results of this study may be beneficial to education researchers as it contributes to the literature in several ways. Information for educators about topic interest and motivation to engage with HABs is largely absent from the literature. There are few studies that have investigated what, if any, differences exist between science and non-science majors in different contexts (Cotner et al., 2017). This study focused specifically on undergraduate science and non-science majors. There are few studies that have explored the interaction and directionality among constructs, such as topic interest, topic knowledge, and attitude within the same study (Heddy et al., 2017). Bråten et al (2009), and Stenseth et al (2016) focused on climate change and nuclear power. This study looks at an emerging scientific issue, HABs. Furthermore, their studies utilized quantitative methods while this study utilized mixed-methods.

Given the range of causes and effects as well as negative consequences related to bloom events, other stakeholders may benefit from this study. There is no one solution to HABs issues and there is no known solution to keeping HABs from occurring (Bauer et. al., 2010). Appropriate and innovative monitoring, and education and outreach efforts are our best hopes for managing HABs issues (Bauer et. al., 2010). HAB education and outreach organizations are likely to find valuable insights from this study on how to better engage the public, misconceptions that continue to persist, and the motivation and interest levels of undergraduates in this sample. Prior to this study, the details related to how undergraduates' may differ in their level of topic interest, topic knowledge and attitudes towards HABs, and the possible interactions between the variables in the context of HABs, were largely understudied. The results of this study may also be useful for science educators as the following quote by Dole and Sinatra (1998) exemplifies the value and usefulness of conceptual change research to educators,

> Regardless of students' existing views, educators hope that students will gain more insight into critical issues facing society and be able to view them from multiple perspectives. This is possible, however, only to the extent that students become highly engaged with the issues and arguments. A better understanding of the change process will help educators create an environment in which students can engage with multiple perspectives (p. 125)

Undergraduate students may also benefit, as this study furthered the discussion of student characteristics that could help improve the overall experiences of learners engaging with scientific issues.

Chapter Summary

Researchers state that HAB events are increasing in frequency, duration, distribution, and severity (Anderson, 2009). Despite the need for the public to have an understanding of HABs in order to mitigate and minimize recovery from the negative effects of HAB events, there iIn addition, misconceptions regarding HABs persist that exacerbate the impacts of blooms (Bauer, 2006; Hardy et al., 2016; Kirkpatrick et al., 2014). To improve functional scientific literacy related to HABs, higher education has been listed as an audience that should be the focus of education and outreach efforts (Bauer et. al., 2010). There is little information to guide education and outreach design for this group or to help higher education instructors in incorporating HABs in their curriculum. The information that is available lacks details that are important in addressing misconceptions; for example, learner characteristics such as interest and motivation. The results of this study may serve multiple stakeholders; education researchers, HABs education and outreach organizations, science educators, and students.

There are four chapters that follow this chapter. Chapter II was a comprehensive literature review on HABs, education and outreach goals, and the CRKM with relation to the prior research on attitudes and knowledge related to HABs. Chapter II also discussed the gaps in the literature and clarified how this study acknowledged those gaps. In Chapter III, the research design and specific details for how the study was conducted are presented. Survey validity and reliability was noted in Chapter III also. Chapters IV and V reported the actual research conducted for this study. The results for the quantitative and qualitative studies were revealed in Chapter IV. Chapter V focused on the interpretations, implications, limitations, and future research related to the study results.

CHAPTER II: THEORETICAL FRAMEWORK

The challenges of communicating HABs are multifaceted like the issue itself, and this chapter is organized around the goals highlighted in the National Plan for Algal Toxins and Harmful Algal Blooms with relation to antecedents that may influence misconceptions and knowledge revision towards HABs. Included in the research goals outlined in the National Plan for Algal Toxins and Harmful Algal Blooms is a need to look at the attitudes and knowledge of diverse audiences (Bauer et al., 2010). The goals included attitudes and knowledge as necessary variables of exploration; however, there is no mention of how interest towards HABs may affect attitudes directly or interact with an individual's prior knowledge to affect their attitudes.

Several studies have considered the variables, topic interest, topic knowledge, and attitudes with relation to other scientific issues (human causation of climate change, risk associated with nuclear power and genetically modified foods) and found useful clues about the relationships between variables (Bråten et al., 2009; Heddy et al., 2017; Stenseth et al., 2016). Although each of the issues mentioned is unique, the methodology and research outcomes from their study can aid in exploring ways to improve HABs education and outreach. This section will discuss harmful algal blooms in more detail and the relevant HABs education and reach goals that give purpose to this study. The cognitive reconstruction of knowledge model that provided the theoretical framework to guide this study is then discussed in relation to prior HABs education and outreach research studies.

Harmful Algal Blooms

To define algae in terms of a harmful algal bloom requires more inclusive criteria. Defining algae in general is first necessary. As of now, they are not recognized as a formal scientific taxon. There is no generally accepted definition for this polyphyletic group of organisms, classification of species frequently changes with emergent research, and many definitions exclude cyanobacteria (Andersen & Lewin, 2019; MacMillan Encyclopedia, 2003; Nichols & Williams, 2017; Speer, 1999).

Algae

Previously categorized as plants, algae differ in that, although they “bloom,” they are non-flowering, lack stomata, xylem, phloem, and other organized tissues that characterize terrestrial plants (Nichols & Williams, 2017). Cyanobacteria contain chlorophyll A pigment, a precursor to plastids, the organelle that unites all eukaryotic algae (Nichols & Williams, 2017; Speer, 1999). Plastids are thought to be the result of an endosymbiotic pairing between a cyanobacterium and a eukaryotic cell, and have evolved into several variations (Speer, 1999); chloroplast in green and red algae are derived from endosymbiotic cyanobacteria (Keeling, 2004), brown algae, diatoms, and dinoflagellates contain secondary plastids derived from an endosymbiotic red algae (Keeling, 2004; Palmer, Soltis, & Chase, 2004). Furthermore, while some species of diatoms are photosynthetic, others retain cyanobacterial endosymbionts that allow for nitrogen fixation but are no longer photosynthetic (Nakayama et al., 2014).

The term algae, in the context of this study, encompasses green, red, and brown varieties; diatoms and dinoflagellates, as well as cyanobacteria or blue-green algae; those that live in fresh, brackish, or marine environments; are photosynthetic or non-photosynthetic; and may include both unicellular micro-organisms and multicellular macro-organisms like giant kelp. In simple terms, algae describes both prokaryotic (kingdom monera) and eukaryotic (kingdom protista), organisms that range from cyanobacteria to close relatives of plants, animals, and fungi (Nichols & Williams, 2017; Speer, 1999). The rationale for including cyanobacteria in the definition of algae as it relates to HABs is that cyanobacteria have the potential to bloom in large numbers and can produce a toxin known as microcystin that poses a significant risk to human health and the environment as a whole (Paerl & Huisman, 2009). The harm algae can cause is therefore categorized in two ways, by production of toxins that spread through the ecosystem and through a variety of environmental impacts that arise from having excessive algal populations (at least one million algae per liter of seawater) (Central and Northern California Ocean Observing System [CeNCOOS], n.d.). It is important to note that there are always exceptions to the rule; this and other definitions of algae may not be able to reflect the diversity of this group of organisms in its entirety at the time of this study or across time. An individual must understand what algae is to be able to recognize HAB species, and the above definition illustrates the complexity and high level of topic-specific knowledge required to be HABs literate to the degree described by HABs education and outreach goals.

Harmful Algal Bloom History

Awareness of algal bloom presence and associated impacts in the US is seen in the resource management and subsistence fishing practices of past and present tribal communities (California Department of Fish and Wildlife (CDFW), 2013; United States Geological Survey GeoHealth Newsletter (USGS), 2016). The CDFW (2013) highlight Meyer, Sommer and Schoeholz's (1928) account of Native California Tribal knowledge,

> From time immemorial it has been the custom among coastal tribes of Indians, particularly the Pomo, to place sentries on watch for Kal ko-o (mussel poison). ...Luminescence of the waves, which appeared rarely and then only during very hot weather, caused shellfishing to be forbidden for two days; those eating shellfish caught at such times suffered sickness and death (p. 20-1).

Though not as commonly practiced today in California, many Alaskan Natives continue to utilize their past and present local knowledge of HABs to mitigate risk and exposure to toxins from bloom events that often occur seasonally (USGS, 2016).

Awareness of algal bloom presence and associated impacts in a global context can be seen in historical scientific records (Codd, Pliński, Surosz, Hutson, & Fallowfield, 2015; Smith & Daniels, 2018). Codd et al. (2015) highlights one of the earliest known records of HABs seen in Kirkby's (1672) report of a "green substance with a(n) hairy efflorescence" that occurred annually between June and August in Lake Tuchomskie, Poland and resulted in the subsequent death of cattle, dogs and poultry that ingested lake water (p. 285).

The impacts of HABs have also been seen in popular culture (Bargu, Silver, Ohman, Benitez-Nelson, & Garrison, 2012). It is said that the popular horror film, Alfred Hitchock's, *The Birds*, was inspired by an event reported in 1961 by a California newspaper that crazed seabirds, numbering in the thousands, pelted the shores and regurgitated anchovies (Bargu et al., 2012). The research by Bargu et al. (2012) suggests that the crazed seabird behavior seen in 1961 could be explained as an effect of being exposed to a HAB toxin from ingesting contaminated anchovies.

Absent from the HABs knowledge highlighted in the above examples is the term *HABs* itself. With modern science, we can look back and see that each example is probably referring to what we would now call a HAB. More importantly, each example also highlights that HABs have been occurring throughout history, in the US and elsewhere. However, prior to the 1970s, only a few regions in the United States were affected by HABs (Falk, Darby, & Kempton, 2000). Researchers have stated that HAB events are increasing in frequency, duration, distribution, and severity; meaning more and more people will be impacted (Anderson, 2009).

One of the first officially recorded and highly publicized HAB events occurred in 1991 in Monterey Bay, CA, when a *Pseudo-nitzschia* bloom produced the biotoxin domoic acid, which contaminated sardines and anchovies, and resulted in the death of the pelicans and cormorants who prey on them (Walz et al., 1994). The 1991 event gave cause for subsequent monitoring of domoic acid concentrations in Monterey Bay and elsewhere.

More than twenty years later, in 2015, a bloom of *Pseudo-nitzschia* species, *P. australis*, produced the highest concentrations of domoic acid ever recorded in Monterey Bay (Ryan et al., 2017). This bloom event was reported by the media to have been caused by warming weather, citing higher water temperatures as the culprit. Researchers tell a different story about the potential causes of the bloom. During the spring transition, a strong upwelling introduced nutrients and actually lessened the warm anomaly that was seen locally (Ryan et al., 2017). Successive upwelling created a favorable environment for growth and accumulation of *P. australis*, making conditions ripe for a bloom (Ryan et al., 2017). High cellular concentrations of domoic acid were associated with the available nitrogen and a disproportionate depletion of silicate in upwelling source waters (Ryan et al., 2017). The 2015 HAB event is one example of how media coverage did not capture the complicated nature of the causes of a bloom, and shows the potential the media has in contributing to misconceptions people have about HABs. This bloom caused hundreds of seabird and sea lion deaths, as well as significant economic loss to fisheries and the shellfish industry (Kudela et al., 2016). It is estimated that due to the 2015 HAB event, the Dungeness crab and rock crab fisheries lost nearly $49 million (Howard, 2016).

Pseudo-nitzschia does not always produce a biotoxin, and the toxin is only harmful when it reaches certain concentrations, but the devastating events of the 1991 and 2015 blooms underline the importance of understanding and communicating the role HABs play in managing resources and in public health. Though there are numerous other examples, both blooms also highlight the potentially detrimental social, economic, and environmental effects, as well as the complexity, and diversity of the causes and impacts of HAB events. Thus the need for effective education and outreach of HABs has gained more attention and become a critical focus for managing HABs.

HABs Education and Outreach Goals

In the National Plan for Algal Toxins and Harmful Algal Blooms, The Harmful Algal Research and Response: A National Environmental Science Strategy 2005-2015, also known as the HARRNESS Initiative, states that a primary goal of the National HAB Educational Outreach Program is to “maintain and disseminate information about HABs to ensure accurate knowledge, attitudes, and perceptions,” (HARRNESS, 2005, p. 65). The authors add that the importance of education and outreach efforts serve to inform the public for the reasons that,

> An informed populace is a prepared one. They will know what a HAB event is, what to expect, and how to respond appropriately. Citizen monitoring networks improve the effectiveness of state monitoring programs by expanding coverage to increase data production for modeling and forecasting (HARRNESS, 2005, p. 75).

A phrase known as the “Human Dimension” has been used by NOAA (2003), Bauer (2006), and Bauer et al. (2010) to frame the broader goals of HABs education, outreach, and research. The Human Dimension is described by Longo and Clark (2016) as having an understanding of the "dynamics of ocean systems, social processes that are changing marine ecosystems, and the perennial interactions within and between these systems," (p. 463).

The follow-up report to HARRNESS 2005-2015, the 2016 Harmful Algal Blooms and Hypoxia Comprehensive Research Plan and Action Strategy developed by the NSTC, as one of five recommendations, continued the call for the need for action (research and development) to improve communication about HAB exposure risks, and causes and effects (NSTC, 2016). Meaning this is still a relevant area of research in improving HABs education and outreach efforts.

One of the research goals to address the HARRNESS initiative goals is the development of audience profiles for diverse subgroups. In terms of working towards increased HABs literacy, audience profiles are intended to inform and guide future resource design (Bauer et al., 2010). The Human Dimensions Research Strategy report refers to the HABs education and outreach efforts discussed above and states, "The success of education and outreach efforts for these outcomes relies on tailoring programs to deliver accessible information to, and harness the participation of diverse sectors…" (Bauer, 2006, p. 42). Higher education students and educators are an example target audience that is listed in the HABs education and outreach initiatives (Bauer, 2006).

HABs education and outreach target audience.

Undergraduate students make up a large portion of voters and consumers, it is calculated that from 2018-2019 there were 21.9 million undergraduates enrolled in US colleges (Duffin, 2019). A survey by Henrich, Heine, & Norenzayan (2010) investigating aspects of psychology, motivation, and behavior of the Western, Educated, Industrialized, Rich, and Democratic (WEIRD) societies, found that American college students are an outlier group and, “are among the least representative populations one could find for generalizing about humans” (p. 2). The authors claim was based on their findings that when compared to the rest of the world, the WEIRD group tended to represent outliers groups, and the range of their responses did not vary systematically in predictable ways. However, as a target audience, American college students in most universities consist of a group of individuals from diverse nationality, age, and socioeconomic backgrounds (Nature Neuroscience, 2010). Little is known about undergraduates’ knowledge, interest, and attitudes towards HABs. Prior research has shown an individual’s attitudes towards scientific issues significantly influence their interest and engagement in science topics (The Science Framework developed by the OECD for the 2015 PISA assessment, 2013). The influence of attitude is so powerful that it can support the subsequent acquisition and application of scientific knowledge (The Science Framework developed by the OECD for the 2015 PISA assessment, 2013). Undergraduates represent a unique subgroup that should be considered in efforts to improve communicating HABs. Understanding their perceptions and attitudes towards HABs will be critical in designing resources that are relevant and reflective of their prior knowledge and interest levels.

Now, more than ever, there is a demand for a greater number of students majoring in science, technology, engineering, and mathematics fields (STEM) (Hernandez, Schultz, Estrada, Woodcock, & Chance, 2013). However, these fields continue to struggle with retention rates (President’s Council of Advisors on Science and Technology [PCAST], 2012). This calls into question pedagogical implications and the student characteristics that affect overall experiences in higher education science courses (Kober, 2015). Further investigation of the differences between undergraduate groups, specifically non-science majors and science majors (those planning a career in science), has gained more attention in recent years (Cotner et al., 2017). A quote from Kober (2015) provides insight into the importance of course structure, design, and resources for student success in higher education science courses:

> A single course with poorly designed instruction or curriculum can stop a student who was considering a science or engineering major. For non majors, an introductory science course that confirms their preconception that they are "bad at science" may be the last science course they ever take (p. xi)

In developing a theoretical model of motivation of non-science majors learning science, a study by Glynn, Taasoobshirazi, and Brickman (2007) reports that in order to increase motivation and achievement in this group, instructors should purposefully connect science concepts to the careers of non-science majors (such as through case studies).

In a follow-up study by Glynn, Brickman, Armstrong, and Taasoobshirazi (2011) comparing the motivation to learn science between science and non-science majors, researchers found that science majors scored higher on all measures of motivation (intrinsic motivation, self-determination, self-efficacy, career motivation, and grade motivation). A study of natural science majors and non-science majors found these groups had similar perceptions on the nature of science and their conceptions ranged on average from somewhat informed to naïve (Miller, Montplaisir, Offerdahl, Cheng, & Ketterling, 2010). The results of Miller et al. (2010) strengthens the findings from studies of science majors in other disciplines (Bezzi, 1999; Parker, Krockover, Lasher-Trapp, & Eichinger, 2008) supporting an emerging trend that nuances among the disciplines may not be as substantive; among science majors in general, there are greater trends seen in nature of science views.

Cotner, et al. (2017) found that non-STEM majors are more likely to have misconceptions about the nature of science but that they do have some understanding of how science works, as compared to biology majors. The authors also found that non-STEM majors were more likely than biology majors to be diverse in regard to their prior knowledge, perceptions, backgrounds, and skills and were less likely to see science topics as personally relevant. Prior studies have shown that there are important and fundamental similarities and differences between the two groups that provide useful implications for designing curricula for all students (Cotner et al., 2017).

The findings indicate that undergraduates could have different misconceptions, attitudes, interest, and knowledge regarding HABs that is influenced by their major being science or non-science. Few studies have been done to investigate what, if any, differences exist between science and non-science majors in different contexts, warranting further study of characteristics that may distinguish these groups (Cotner et al., 2017).

The CRKM provided the theoretical framework to guide this study because it combined both characteristics of learners and the message being presented. It is also useful in the study of conceptual change and has been used by previous education researchers in the study of other scientific issues. The next section describes the parts of the model with relation to prior HABs studies.

Cognitive Reconstruction of Knowledge Model (CRKM)

An informed and prepared, or HABs literate populace, must understand the scientific, environmental, social, and political components of HABs; how they interact to make bloom events complex and diverse; their role in forecasting; and how their own actions contribute to, as well as serve to, mitigate and reduce the impacts of HAB events. For one to be HABs literate, they must also understand the tentative and emergent nature of HABs research and issues whilst still trusting research and monitoring agencies. The relationship between misconceptions about HABs and behaviors that are not supported by evidence often contributes to the tangle of social and political components that are inherent in HABs issues (Wells et al., 2015).

To attain a level of HABs literacy as described by the HARNESS goals may require an individual to learn new information or to change their misconceptions based on new information. They will also need to develop an awareness of the misconceptions that contribute to attitudes which may be unsupported by evidence but that can have an effect on behaviors. Revising misconceptions or updating inaccurate knowledge is a learning process known as conceptual change, described as a form of knowledge revision that includes modifying emergent attitudes (Kendeou et al., 2014). Based on the work of Sinatra and Pintrich (2003) and Vosniadou (2013), Heddy et. al. (2017) provides a concise operational definition of conceptual change, which is followed for the purpose of this study: “the process of restructuring conceptual knowledge about a phenomenon from nonscientific views toward accepted scientific perspectives” (p. 514).

An implicit prerequisite of conceptual change is that there are pre-existing misconceptions related to the topic at hand; it is crucial to assess what those prior conceptions are before trying to address them. A misconception, for the purpose of this study, is defined as “an understanding that is different from what is scientifically accepted” (National Research Council, 2012 as cited in Heddy et al., 2017, p. 514). Therefore the goal of conceptual change is to move individuals from their misconception(s) to the accepted scientific perspectives (Heddy et al., 2017). The CRKM has been used in previous studies that address the conceptual change process in issues such as climate change, nuclear power, and GMO's to review relevant factors, interest, knowledge, and attitudes (Bråten et al., 2009; Heddy et al., 2017; Stenseth et al., 2016).

The CRKM seeks to facilitate or constrain knowledge revision, proposing that the change process begins by investigating the interaction between learner (prior knowledge, attitudes, beliefs, and motivation) and message characteristics (comprehensibility, plausibility, coherence, and rhetorical structure) (Dole & Sinatra, 1998). The CRKM combines theories from the three disciplines of social psychology, science education, and cognitive psychology to conceptualize change using a cognitive constructivist framework (Dole & Sinatra, 1998). The CRKM was selected as the theoretical framework to guide this study because it aligns with desired outcomes of HABs literacy. An understanding of the role of attitudes and prior knowledge in conceptual change is central to HABs education and outreach research goals. Although theoretical perspectives on conceptual change and the nature of misconceptions have traditionally emphasized investigating cognitive structures, researchers have started including the role contextual factors, motivational factors, and affective constructs (moods and emotions) play in the process (Heddy et al., 2017; Pintrich et al., 1996).

In the model, factors for knowledge revision are described in terms of "Hot" (motivational and affective) and "Cold" (information processing) (Dole & Sinatra, 1998; Stenseth et. al, 2016). The CRKM proposes that learner and message characteristics interact to influence levels of information processing on a cognitive engagement continuum (Dole & Sinatra, 1998). Learner characteristics and message effects are hypothesized to have a nonlinear relationship and the change process can be initiated by either learner or message characteristics

(Dole & Sinatra, 1998). Model interactions are depicted in Figure 1 and the main parts of the model, message characteristics; learner characteristics; and the engagement continuum are described in the following sections.

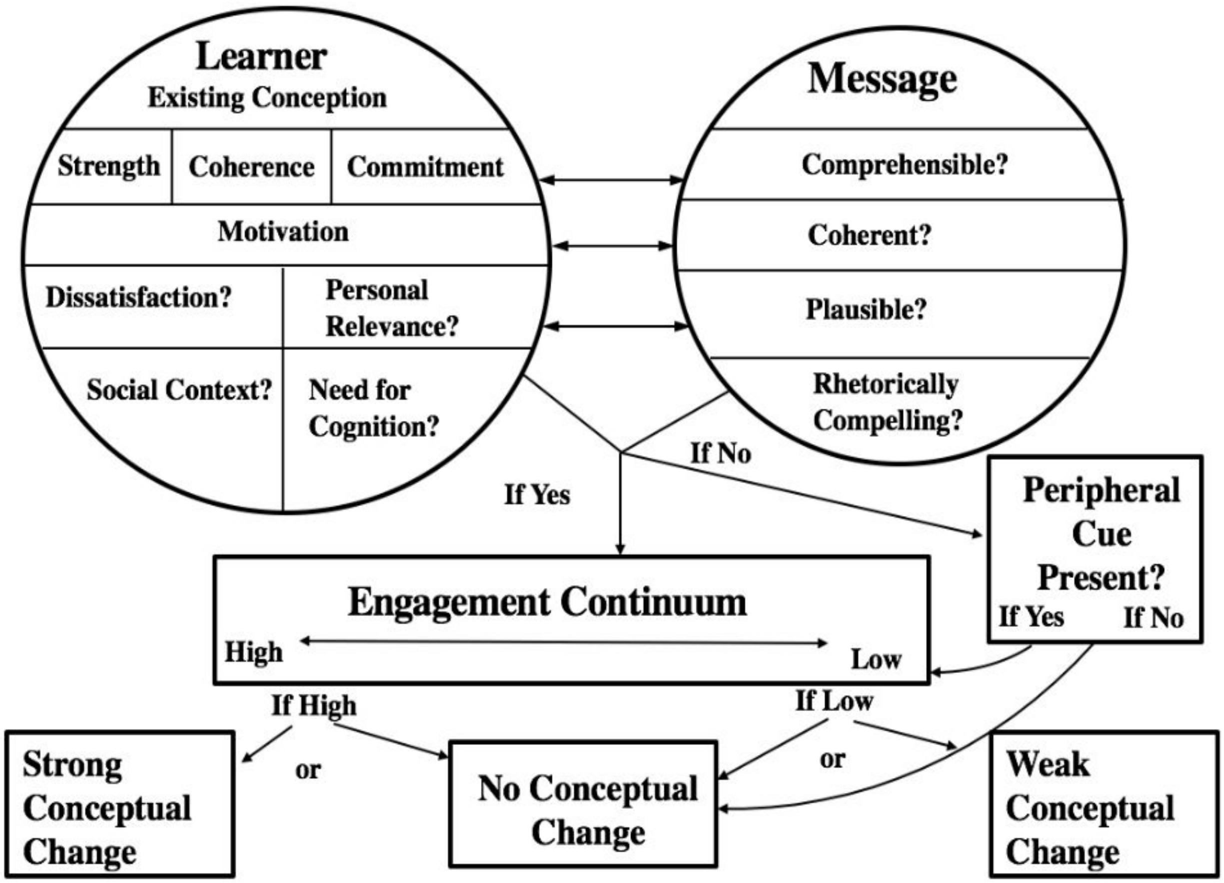

Figure 1. Cognitive reconstruction of knowledge model.[1]
Note. Arrows represent directionality of model interactions to posit the likelihood of conceptual change given the variables (Dole & Sinatra, 1998, p. 119).

Message Characteristics

Each message is comprised of a unique set of variables (format, organization, and task inferred in the message) that interact with an individual's learner characteristics and influence

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message characteristics (the degree to which the message is perceived as comprehensible, plausible, coherent and rhetorically compelling) (Dole & Sinatra, 1998).

For a message to be comprehensible, an individual must have sufficient background knowledge to relate to the message and the message must not be too conceptually difficult for the individual to process it (Dole & Sinatra, 1998). The plausibility of a message is based on an individual weighing the quality of evidence to decide that a message could be reasonably true; essentially this involves assessing the credibility of a message (Dole & Sinatra, 1998). Individuals will be less motivated to process messages that they do not find comprehensible and plausible (Dole & Sinatra, 1998). For a message to have coherency, “it must provide an explanation of the phenomenon that links ideas into a conceptual whole” (Dole & Sinatra, 1998, p. 120). For a message to be rhetorically compelling to an individual it can not be ambiguous, confusing or disjointed; the language usage, sources of information, and justifications that form the message must be persuasive and convincing (Dole & Sinatra, 1998). Existing conceptions, motivation, and message characteristics can thus be conceptualized as an interacting dynamic system.

Change can also occur through peripheral cues, in spite of an individual having low motivation to change or an individual finding a message incomprehensible and uncompelling. Dole and Sinatra (1998) posit that although peripheral cues usually induce change at a superficial level that is weak, temporary, and strongly susceptible to further change, peripheral cues also have the potential to encourage individuals to engage at a high level with topics. An example of a peripheral cue would be presenting the issue or argument from a relatable perspective, such as, instead of a scientist or government agency, a farmer reports to other farmers about the effects certain farming practices can have on triggering harmful algal blooms.

Harmful algal blooms message characteristics.

Prior studies provide insight into HAB message characteristics. Hardy et al. (2016) describe that effectively communicating HABs includes aspects of both education and notification and that these elements overlap. “For example, notifications of specific HAB events often include information to educate the public about the causes and potential risks” (p. 71). Hardy et al. (2016) found that although several states have developed protocols for notifying the public of bloom events, national guidelines for effective communication strategies, alerting the public of HAB presence or HAB health risks are lacking. A reason for the lack of effective communication strategies may be due to the inherent diversity and complexity of HAB events which often have specific local and regional impacts (HARRNESS, 2005). Given this, it is likely that individuals could have different levels of knowledge about HABs depending on their prior experiences. As there is no scientific definition for algae or a consensus threshold for determining bloom events, it is also likely that differing messages could affect the degree to which individuals find HABs messages to be comprehensible, plausible, coherent, and rhetorically compelling.

Learner Characteristics

Learner characteristics (motivational and affective) are central to conceptual change in the CRKM and in order to effectively leverage the CRKM in facilitating conceptual change, an understanding of learner characteristics is critical. The learner characteristics described below are prior knowledge and motivation.

Prior knowledge.

Prior knowledge is the first learner characteristic considered in the model. An individual's existing conceptions include their attitudes about an idea, event, or phenomenon and their topic knowledge; collectively this is referred to as prior knowledge (Dole & Sinatra, 1998). Prior knowledge has been cited in the literature as an impactful antecedent to knowledge revision of misconceptions that results in conceptual change (Broughton, Sinatra, & Nussbaum, 2013; Dole & Sinatra, 1998; Gregoire, 2003; Heddy et al., 2017).

Attitude.

Attitude is described in terms of simple object evaluation whereby a positive or negative evaluation of an object, person, idea, or event leads to a response that lays somewhere on a scale from favorable to disfavorable (Eagly & Chaiken, 1993; Heddy et al., 2017). Simple object evaluation associations can be described as follows: attitudinal object (i.e., harmful algal blooms) is one node within a semantic network, the evaluation of the object (i.e., beliefs about HABs) is the other, while the link between the two represents the strength of the association (Fabrigar, MacDonald, & Wegener, 2005). Typically, larger networks of associated knowledge structures are linked or embedded within simple object evaluations. For example, HABs (object of evaluation) could be evaluated based on a set of beliefs that HABs pose a risk to eating seafood at restaurants during a HAB event (attributes of the object), and the strength of these beliefs associated with the topic of HABs could result in an overall negative attitudinal appraisal of HABs which influences people to eat less seafood.

A negative attitudinal appraisal, in this case, could stem from misconceptions derived from inaccurate HABs prior knowledge and attitudes. Such an appraisal could further result in individuals ignoring alerts regarding bloom events and developing a distrust in reporting, monitoring, and research agencies. Positive attitudes in this study can be interpreted as an individual having accurate beliefs about the causes ,effects, and risks associated with HABs. This example of object evaluation has been reported in prior studies and identified as having an influence on the severity of the economic impacts felt by and the recovery from bloom events (Howard, 2016). Including attitudes towards HABs in the analysis allows for the opportunity to identify persistent misconceptions, gauge the degree to which attitudes accurately reflect desired perceptions, and examine the potential role of interest and knowledge in predicting attitudes. It is necessary to explore attitudes because an inaccurate or negative attitude towards HABs can lead to persistent misconceptions about HABs that are difficult to change.

Topic knowledge.

Information that is necessary to assess an issue and arrive at a reasoned attitude is known as topic knowledge (Petty & Briñol, 2012; Petty & Wegener, 1999). As the complexity of the issue increases, it requires more background information to understand and can thus require higher levels of topic knowledge (Petty & Wegener, 1999). The relationships between knowledge and motivation are sophisticated. Higher topic knowledge can decrease the role of motivation causing someone to make an evaluative judgement on an issue-based solely on their topic knowledge (Petty & Wegener, 1999), while someone with less knowledge may rely more on their personal involvement in the issue when taking a stance (Murphy, 2001). To make sense of a message requires an individual to have sufficient background knowledge (Dole & Sinatra, 1998). To be HABs literate, an individual must have factual and conceptual topic-specific knowledge to be able to make informed decisions and arrive at reasoned attitudes (HARRNESS, 2005).

Dole and Sinatra (1998) identified three qualities of a learner's prior knowledge that are relevant in influencing the likelihood of change; strength, coherence, and commitment. Strength describes the richness of an existing idea, asking if the idea is detailed and well-formed or is it sparse and disjointed (Dole & Sinatra, 1998). Conceptual change is less likely to occur the stronger the existing idea is (Eagly & Chaiken, 1993). Existing conceptions that can provide a complete and accurate evidence-based explanation of an idea, event, or phenomenon are described in terms of their conceptual coherence (Dole & Sinatra, 1998). To provide a coherent explanation about the risks, causes, and effects regarding HABs would require topic knowledge that supports accurate beliefs. For example, a coherent explanation that provides evidence for the belief that it is not safe to harvest shellfish during a harmful algal bloom should include the reasons that, depending on a variety of factors, colonies of algae can grow out of control and sometimes produce toxins but also that not all blooms are harmful, not all species of algae produce toxins, and toxicity depends on concentration levels. Because algae is food for many organisms, toxins can spread through the food web thus posing a risk of exposure to toxins from shellfish harvested during bloom events. In the example provided, conceptual coherence might be lacking in that participants do not fully grasp food web relationships or connections between toxin and concentration levels for toxicity. Existing conceptions are more susceptible to change when conceptual coherence is lacking (Thagard, 1992).

Commitment to existing knowledge is described as the robustness of attitudes and beliefs towards the value of a conception and is also assumed in the model, in part, to determine the likelihood that an individual will change previously acquired knowledge (Dole & Sinatra, 1998). Despite the strength and/or coherence of prior conceptions, the more an individual is committed to their existing ideas, the less likely they are to change them (Dole & Sinatra, 1998). Dole and Sinatra (1998) highlight the difficulty and importance of assessing prior knowledge, "individuals differ in the quantity and quality of prior knowledge, which can interfere with learning, interpreting, and evaluating new information" (p. 118).

Motivation.

The second learner characteristic considered in the CRKM is an individual's motivation to process new information (Dole & Sinatra, 1998). Four interrelated facets of motivation are identified; dissatisfaction, personal relevance, social context, need for cognition (Dole & Sinatra, 1998).

Dissatisfaction.

The process of conceptual change can be facilitated when one is presented with a cognitive conflict that arises between learning new discrepant information that is not aligned with existing conceptions and prior knowledge, or a dissatisfaction with existing conceptions (Chan, Burtis, & Bereiter, 1997). The dissonance experienced between existing and emergent information, coupled with attempts to reduce the cognitive disequilibrium felt, makes conceptual change different from other types of learning where information is merely added or assimilated to construct new knowledge structures or fill in incomplete knowledge gaps (Chi, 2009; Vosniadou, 1994). Engaging in such a conflict can result in an attempt to revise knowledge structures, beliefs, and prevailing attitudes so that they more accurately reflect knowledge structures within the conceptual framework (Lombardi, Nussbaum, & Sinatra, 2016). Science education instruction can provide a space where an individual can experience such dissonance by engaging with multiple perspectives (Dole & Sinatra, 1998).

Personal relevance.

Considered as a possible alternative source of motivation to process new and/or conflicting information, individuals can be motivated by personal relevance to change existing conceptions and not just by dissatisfaction with existing conceptions (Dole & Sinatra, 1998). Personal relevance in terms of the CRKM could mean having a stake in the outcome (Chaiken & Stangor, 1987), an interest (Alexander, Kulikowich, & Jetton, 1994), high emotional involvement (Gaskins, 1996), and/ or high self-efficacy related to the topic (Parajes, 1997).

Topic interest.

Interest is a prominent research subject in motivation theory (Hidi, 2001; Schiefele, 1999, 2009; Schunk, Meece, & Pintrich, 2014; Wigfield & Eccles, 2000) and theories of domain learning (Alexander, 1997, 2012; Buehl, Alexander, & Murphy, 2002). Despite the influence an individual's interest level can have on learning about a topic, educational objectives often do not consider student interest (Zeidler & Nichols, 2009). Prior studies highlight the significance of interest in learning; interest in a domain can positively predict performance within that domain (Schunk et al., 2014). The motivation or will to engage in a specific topic denotes the level of an individual's topic interest (Schunk et al., 2014). Topic interest in this study can be described as a relatively stable motivational disposition to be attracted by and engaged in specific topics or domains, in this case, HABs (Schunk et al., 2014). Motivation to process a message can be promoted by high topic interest (Dole & Sinatra, 1998). Interest could then be leveraged to increase an individual's motivation to change their misconceptions (Dole & Sinatra, 1998).

Social contexts.

Social contexts are the third facet of motivation accounted for in the CRKM that can influence an individual to process information with high levels of engagement. For example, peers showing interest in a topic or convincing viewpoints may motivate others to process the information they would not have otherwise considered (Dole & Sinatra, 1998). Social context extends to interactions that include family, community, school, peer, or other group members that have an influence on an individual's behavior or thinking (Dole & Sinatra, 1998).

Need for cognition.

The need for cognition, the inherent motivation to process information, intrinsic motivation in other words, is the fourth facet of motivation discussed in the CRKM (Dole & Sinatra, 1998) and is best described as an alacrity to "engage in an activity for its own sake," (Pintrich & Schunk, 1996, p. 275). Individuals motivated by a need for cognition also show persistence in their consideration of information and new ideas (Dole & Sinatra, 1998). Dole and Sinatra (1998) categorize a learner's existing conceptions and their motivation to process a message as "critical features of the message itself" (p. 120).

Attitudes and knowledge regarding HABs.

Prior education and outreach research provides insight into HAB learner characteristics; attitudes, prior knowledge, and misconceptions. Research conducted by Nierenberg et al. (2010) used a survey to look at tourist versus residents' knowledge of Florida red tide and showed that out of the 100 tourists and 92 residents only one tourist from the entire group had not heard of a Florida red tide. Nierenberg et al. (2010) reported that responses to "when can a red tide occur?" showed the greatest range between tourists and residents and that tourists frequently thought that red tide is caused by weather changes and most people identified pollution and fertilizers as the main cause for red tide, despite the correct response being “it isn't known.” A subsequent survey conducted by Smith et al. (2014) to understand what fishermen know about freshwater HABs in Louisiana indicated that all participants had heard of algal blooms but that only 40% had heard of HABs. Both studies found widely inconsistent and incorrect responses across participating groups, likely signifying a substantial lack of knowledge and prevalence of misconceptions in the public’s knowledge of HABs (Nierenberg et al., 2010; Smith et al., 2014). Kirkpatrick et al. (2014) utilized the survey developed by Nierenberg et al. (2010) and found overall knowledge about Florida red tide events had not changed in subsequent years. Furthermore, they found that knowledge did not differ by age, gender, or education level. A finger on the pulse, so to speak, of the public’s knowledge about and attitudes towards HABs is necessary for effective communication and accurate appraisal of persistent misconceptions (Nierenberg et al., 2010).

Cognitive Engagement Continuum

The cognitive engagement continuum is described in terms of low, medium, and high (Dole & Sinatra, 1998). The continuum is meant to represent the range of engagement levels people have when thinking about an issue (Dole & Sinatra, 1998). The CRKM assumes that the highest level of engagement would entail deep thinking, processing, and reflection on one’s progression through conceptual change (Dole & Sinatra, 1998). The CRKM also assumes that to achieve lasting conceptual change, attaining high engagement levels on the continuum is necessary.

Low cognitive engagement is described as “active consideration of ideas,” and requires little reflective or metacognitive thought, relying on relatively simple strategies of information processing like maintenance rehearsal and mnemonics, (Dole & Sinatra, 1998). Although low cognitive engagement could lead to the assimilation of new information into existing conceptions, it could also result in little significant change to those conceptions, or to new ideas being remembered but not integrated into existing conceptions (Chinn & Brewer, 1993; Dole & Sinatra, 1998).

Moderate cognitive engagement requires a "greater depth of processing, more elaborate strategy use, and some reflective thought or metacognitive regulation" (Dole & Sinatra, 1998). Activities such as answering inferential questions related to readings (Benton, Glover, & Bruning, 1983) and drawing personal connections to content (Morrow, Pressley, Smith, & Smith, 1997) are a few ways an individual may make meaningful connections with their existing conceptions at a moderate level of engagement (Dole & Sinatra, 1998).

High cognitive engagement is described as "deep, analytical, critical reflection and awareness, and regulation of thought process." It involves an individual connecting and comparing existing conceptions with new information, reflecting on what they were thinking and why, and considering evidence for both arguments and counterarguments (Dole & Sinatra, 1998, p. 121). Dole and Sinatra (1998) further assume that when an individual has a deep level of engagement with the content, lasting conceptual change is more likely to follow, and that "conceptual change depends on the outcome of the engagement process as it interacts with the learner and message characteristics" (p. 122). Student-to-student interaction and authentic student experiences with science and engineering practices have also been cited as strategies to better engage students in learning about science (the domain itself) and science issues (topic specific content) (Kober, 2015). Instructional practices can be leveraged to facilitate high levels of cognitive engagement.

Although there are situations where conceptual change was not achieved despite an individual's level of engagement (scientists debate and eventually reject cold fusion), it is considered the most important aspect of the change process (Dole & Sinatra, 1998). An individual is more likely to process information when the interaction between learner and message characteristics is positive. In addition, lasting change is more likely to occur when a positive interaction is fostered through high levels of cognitive engagement (Dole & Sinatra, 1998). Educational activities can be designed to provide the opportunity for high levels of cognitive engagement by leveraging data gathered about HAB learner and message characteristics.

Relationships Between Interest, Knowledge, and Attitudes

Sinatra and Seyranian (2016) have developed a 2X2 matrix that is useful in describing the conditional relationships between attitudes, conceptual knowledge, and knowledge revision. The matrix posits that more accurate conceptual knowledge is related to more positive attitudes and that less accurate conceptual knowledge is related to more negative attitudes (Sinatra & Seyranian, 2016). The matrix predicts that moving from more negative to more positive attitudes is a necessary process in knowledge reconstruction (Sinatra & Seyranian, 2016).

For the context of this study, one would then assume that if an individual has less accurate conceptual knowledge related to HABs, then they are likely to have negative attitudes towards risk, causes, and effects of HABs. For risk the scenario could play out in two ways, a lack of conceptual understanding for example that HABs are sometimes colorless could cause an individual to ignore alerts to avoid swimming during bloom events because they don't see any color indicating the presence of a bloom (CeNCOOS, n.d.). Alternatively, an individual could assume due to lack of conceptual knowledge that there is a high level of risk and have an “over-reaction” to alerts; anytime they see color, they associate it with a harmful bloom species and avoid ocean activities (CeNCOOS, n.d.). An example of this can be seen in May 2011, in Monterey Bay, CA when a non-photosynthetic dinoflagellate called *Noctiluca scintillans* formed an orange slick about an inch thick on the surface of the bay waters and at first caused alarm to ocean recreaters (CeNCOOS, n.d.). The slick was produced as the bloom matured and densely packed cells aged which increased their buoyancy and caused them to float to the surface (CeNCOOS, n.d.). *Noctiluca scintillans* is a bioluminescent species and can produce a sparkling display of lights as waves crash ashore or around boats at night (CeNCOOS, n.d.). This is a good example of a bloom that did not produce a toxin and had little to no harmful impacts (CeNCOOS, n.d.). However, one could have negative views regarding a topic but still be interested in the topic (Krapp & Prenzel, 2011). Thus understanding the role interest has with relation to knowledge and attitudes regarding HABs is important to consider.

Regarding climate change, Bråten et al (2009) compared and contrasted the topic interest, topic knowledge, and attitudes between undergraduates from Norway who were enrolled in an introductory educational science course, and from Spain who were enrolled in an introductory psychology course. Their study found that topic interest about climate change was a better predictor of beliefs across the two cultures than was topic knowledge. The Norwegian undergraduates had higher topic knowledge but lower topic interest scores than Spanish undergraduates. Researchers stated that cultural context was likely a factor in why the two groups differed; climate change was more of a prominent topic of discussion in Norway at the time. So presumably, Norwegian students may have higher topic knowledge but because it is discussed more, may not be as interested.

Kahan et al. (2012) showed that while science knowledge was not related to concerns about the risk of climate change, interest and values were. Interest was also demonstrated by Gauchat (2012) to have an influence on the formation of people's attitudes towards scientific issues. The results of the study indicate that the influence of interest and values become stronger as education level increases (Gauchat, 2012).

Stenseth et al. (2016) describe how attitudes are predicted by interest and knowledge about climate change and nuclear power. Attitudes towards climate change were shown to become more positive as interest level increases, despite the level of knowledge (Stenseth et al., 2016). However, attitudes towards the risk of nuclear power become more negative as highly knowledgeable people become more interested in the topic (Stenseth et al., 2016). The opposite is seen for those who have low interest and knowledge of the subject; as interest increases, attitudes become more positive towards risk associated with nuclear power (Stenseth et al., 2016).

Even with the emphasis in theory on "warm conceptual change," few studies have explored the interaction and directionality among several hot constructs such as interest, knowledge, and attitude, within the same study (Heddy et al., 2017; Stenseth et al., 2016). The findings highlighted above suggest a need to continue investigating the relationships that may exist between these variables in different contexts and cultures, and to use this information to develop high cognitive engagement opportunities.

Chapter Summary

The complexity of HABs requires a high level of topic-specific knowledge to be HABs-literate. Although HABs have been occurring globally throughout history, they were not referred to as HABs in most cases. In the US, prior to the 1970s, only a few regions in the United States were affected by HABs. However, researchers have stated that HAB events are increasing in frequency, duration, distribution, and severity. HAB events can have devastating effects on humans and marine life, as well as economic repercussions. The need for effective education and outreach of HABs has gained more attention and become a critical focus for managing HABs.

Increasing HABs literacy and addressing persistent misconceptions related to HABs among specific audiences has been the focus of education and outreach efforts. Among undergraduate students, major, science or non-science, has been shown to have an effect on attitudes and motivation to learn about science topics (Cotner et al., 2017). There may be important differences between groups of undergraduates that could affect attitudes, interest, or prior knowledge related to HABs.

Changing misconceptions or conceptual change may be required to address persistent misconceptions. The CRKM considers the relationships between learner and message characteristics that influence conceptual change and considers the level of cognitive engagement as an additional important aspect of conceptual change. Understanding these characteristics in relation to HABs could aid in addressing persistent misconceptions that may exist in undergraduate students. Prior HABs education and outreach research has shown that the general public has persistent misconceptions related to HABs that need to be addressed. HABs education and outreach guidelines recommend that effective communication relies on an understanding of an audience's attitudes and knowledge. Information about topic interest and motivation to engage with HABs is largely absent from the literature. There are few studies that have explored the interaction and directionality among constructs (such as interest, knowledge, and attitude) within the same study in different content areas (Heddy et al., 2017). Yet, important relationships have been shown between topic interest, topic knowledge, and their usefulness in predicting attitudes.

Higher education has been identified as a target audience but little is provided to assist educators in utilizing HABs as a course topic. There is a knowledge gap as to what different groups of undergraduates' levels of interest, knowledge, and attitudes towards HABs can tell us about how best to address their misconceptions. This study was an opportunity to gain insight into important learner characteristics that may affect how misconceptions towards HABs should be addressed. The goal of this study was to explore the antecedents that influence misconceptions regarding HABs and use the study results to make implications for educators to implement HABs into their instruction. An overview of the mixed-methods approach, using quantitative and qualitative data to explore the study research questions, is provided in Chapter III.

CHAPTER III: METHODS

To address the research questions, an exploratory mixed methods study was conducted that utilized QUANTITATIVE and qualitative methods. The QUANTITATIVE phase represents the bulk of the data collection and is the main focus for the discussion of this study. It consisted of three parts: survey design, followed by a pilot and revision stage, and the use of the revised survey in a data collection stage. The qualitative phase represents a much smaller focus of the study and its primary purpose was to support the QUANTITATIVE analysis and discussion. The qualitative phase consisted of one-to-one follow-up interviews with volunteer survey participants. Data collected from each phase were used for the results and discussion chapters of this study.

Using the methodology by Vaske, Donnelly, Wittmann, and Laidlaw (1995), the study used past research to develop and test research questions based on a theoretical distinction between science and non-science majors, relationships between topic interest, topic knowledge, and attitudes, and the CRKM provided the medium for understanding the specific situation of improving HABs education and outreach efforts. In terms of this study's context, "Human Dimension," exemplifies its purpose, and refers to "an area of investigation that attempts to describe, predict, understand and affect human thought and action toward natural environments," (Manfredo, Vaske, & Sikorowski, 1996, p. 1). To view the Institutional Review Board approval document as well as the associated consent document, please see Appendix A and B. The methodology of each phase of this study, QUANTITATIVE and qualitative, are detailed below.

Quantitative Methodology

The survey was designed using the methodology suggested by Vaske (2008); it was first designed and created, the survey was then piloted and revised. The purpose of the pilot stage was to assess the reliability and validity of survey questions in order to make improvements and revisions to the survey. The revised survey was then administered and data collected were statistically analyzed to provide insight into the research questions asked in this study. This section first describes survey design and measures, then the settings and participants for the survey, the reliability and validity of the survey, and lastly the statistical analysis methodology of survey data.

Survey Design and Measures

This study incorporates a modified version of the survey methodology used in the studies by Stenseth et al. (2016) and Bråten et al. (2009). This study's survey consists of four parts and is given in the following order; attitude, topic interest, topic knowledge, and demographic questions. Before each survey part, participants were given some brief instruction and context for the questions. The study variables are described below. Please see Appendix C, for the pilot survey instrument and Appendix D, for the study survey instrument.

Topic interest measure.

To investigate participants general interest in harmful algal blooms, a 14-item interest measure was created by modifying interest measures validated in prior research for the topics of climate change (McCrudden, Stenseth, Bråten, & Strømsø, 2016; Strømsø, Bråten, & Britt, 2010) and nuclear power (Stenseth et al., 2016). Participants were asked to rate their level of interest with statements on a 10-point scale ranging from 1 (not at all true of me) to 10 (very true of me) (Stenseth et al., 2016).

The items were developed to allow participants to report their interest in issues and activities concerning harmful algal blooms from passive and active involvement standpoints and assumes this reflects participants' willingness to take action (Stenseth et al., 2016). This measure also assumes that a low score would reflect participants' disinterest in the topic while a high score would indicate a higher level of engagement in the topic (Stenseth et al., 2016). Example items include, "I'm interested in issues concerning harmful algal blooms; I participate in discussions on harmful algal blooms."

Attitude measure.

To gain an understanding of participants' attitudes towards harmful algal blooms, a 19-item measure was developed for this study, 11 items intended to measure cause and effect attitudes and 8 items to measure risk attitudes. Participants were asked to rate their level of agreement with statements on a 10-point scale ranging from 1 (not at all true of me) to 10 (very true of me) (Stenseth et al., 2016). Items are based on attitude measures from the Stenseth et al. (2016) study that looked at participants' feelings toward human causation of climate change and general risk perception towards nuclear power were modified for harmful algal blooms. Example items include, "I believe that harmful algal blooms can be caused by human activities; I believe that harmful algal blooms can have effects on human health." Specific risk perception statements were taken from Nierenberg et al. (2009) Florida Red Tide risk perception survey and modified to focus on harmful algal blooms in general. Example items include, "I believe it is safe to swim during a harmful algal bloom; I believe it is safe to harvest shellfish during a harmful algal bloom." Additionally, items regarding the diversity of the effects of HABs were included. Examples include, "I believe that harmful algal blooms can affect and are relevant to my daily life; I believe the effects of harmful algal blooms can be seen globally."

It is important to note, prior use of the attitude measures assumes that if students hold that climate change is caused by humans, then their scores for these measures would be high, while low scores would be indicative that they do not endorse this idea (Stenseth et al., 2016). Similarly, concern for nuclear power plants measures assumes that a high score would indicate a high level of risk perception and a low score would indicate safe, low-risk perception (Stenseth et al., 2016). Stenseth et al. (2016) further assume that attitude ratings for climate change give insight to the scientific consensus about the causes of climate change, while nuclear power ratings give insight about the strength of attitudes that are not supported by scientific evidence. Two concerns in HABs education and outreach are that people have misconceptions about risks that are not supported by research and also the effects of blooms and the role humans play in causing blooms. Based on the discussed assumptions, it is appropriate to use the attitude measures described above. In this study, a high score on the risk scale would mean that participants thought HABs were safe and low risk, a low score would indicate participants viewed HABs to be a risk. High score for cause and effect attitudes would mean participants believe that HABs are in part caused by humans and that bloom events have a wide range of effects, from economic and political to human health and environmental.

Though the attitude measures are based on prior studies and can provide useful insights, they have their limits. A limitation of this measure as a whole is that it focuses on general attitudes towards HABs and does not provide an in-depth assessment of the cognitive, affective, and behavioral details that can influence one's attitude. It also does not ask about specific types of HABs, regionally or locally.

Topic knowledge measure.

In order to assess participants' prior knowledge about harmful algal blooms, a 14-item knowledge measure was developed modeling the knowledge measure developed by Stenseth et al. (2016) for nuclear power and Bråten et al. (2009) for climate change. The aim of the knowledge measure questions was to address factual and conceptual knowledge related to information central to HABs outreach using questions ranging from difficult to easy. Question difficulty was determined and modeled after the question progression style in the Stenseth et al. (2016) study. Additionally, items were designed to reflect common misconceptions people have about HABs. For example:

A harmful algal bloom is

a. rapid and uncontrolled growth of algae that ALWAYS secrete toxins.
b. rapid and uncontrolled growth of algae that can sometimes secrete toxins.
c. rapid and uncontrolled growth of algae that DOES NOT secrete toxins.
d. rapid and uncontrolled growth of any kind of algae.
e. none of the above.

Algal blooms

f. are increasing in frequency and duration.
g. are increasing in frequency and decreasing in duration.
h. are staying the same.
i. are increasing in duration and decreasing in frequency.
j. are decreasing in frequency and duration.

A preliminary version of the topic knowledge measure was developed by modifying questions from Nierenberg et al. (2010) Florida Red Tide survey, incorporating the most pertinent HAB knowledge from NOAA, CDC and NIH websites as well as including emerging HABs issues gained from interviews with multiple experts in the field. The preliminary version was reviewed by an expert in marine science and science education to establish validity.

Feedback resulted in minor changes to questions and response options for purposes of clarity, accuracy, and readability. The expert reviewer also paid close attention to the correct answers and the distractors for alternative or misleading responses. During the knowledge measure, in questions 1-14, participants were asked to choose one answer that is most accurate out of the five multiple-choice options. For participants' knowledge score, a composite of the number correct out of 14 items was used for analysis.

This measure assumes that scores will reflect the level of general HABs knowledge participants have and what misconceptions continue to persist. A limitation of this measure is that there is no way of knowing how many people guessed and on what questions. Arguably, if participants guess and are still able to select the correct answer, then they would probably be able to discern the necessary information to make at the very least, partially informed decisions.

Demographic questions.

Questions regarding participants' basic background information were also asked in the survey and are listed as follows: "What is your intended or declared major?; What is your gender?; Where have you lived most of your life?". The first question is asked in order to establish the participant group; the second question's purpose is to be able to compare the results to prior studies that control for gender. However, prior perception surveys on HABs indicated that there is no difference between gender, age, or region, and what people know or feel towards the topic so those variables were not included as part of the research questions for this study, and only gender was used as a control (Kirkpatrick et al., 2014). Gender is used as a control variable for statistical tests following the methodology of the Stenseth et al. (2016) study. The third question was asked because HABs knowledge is thought to vary greatly by region, with people who live near the coast or another body of water to have more knowledge and understanding of the issues that cause HABs as well as the possible effects. The US census format for categorizing states into regions and divisions was used for survey options, US territories and international were also added as options.

Survey Setting and Participants

For both the pilot and subsequent data collection stage, the survey was administered electronically through Qualtrics and participants could complete it anytime within three weeks. Instructors provided an announcement and email for students to participate in the survey via the Qualtrics link. Participants were able to take as long as they needed, though the survey was designed to take no more than 15 minutes to complete. Survey participants were first presented with an informed consent question; if they were over the age of 18 and consented to participate in the study, they were then directed to the start of the survey. Participants were from a large, private, research-intensive university in the northeastern region of the United States and grouped based on their self-reported majors as either science or non-science majors.

Pilot survey participants.

The survey was piloted in the Spring of 2019. Participants were from a pool of science and non-science majors recruited from a science course for non-science majors and an introductory level biology course for science majors. Participants ranged from freshmen to seniors. A total of n=127 participants took the survey; n=1 did not consent to participate and only n=65 completed the survey in its entirety. Given a low response rate of 51% for the pilot with very low participation among science majors, an incentive was added when the revised survey was administered and this data was not used for this study. Please see, Appendix G: Pilot Survey

Participants by Gender and Major, and Appendix H: Pilot Descriptive Statistics for Study Variables, *N*=65 for further details about the pilot survey participants.

Survey participants.

In the fall 2019 semester, using convenience sampling, survey participants were recruited from a pool of non-science majors in a science course and science majors in three biology courses. The courses were selected at first to represent participants who would have an introductory level of science knowledge. Due to recruitment issues in the pilot study, additional biology courses were added to the sample pool. Participants ranged from freshmen to seniors. An incentive to be entered into an Amazon gift card drawing was offered to encourage the recruitment of survey participants. To be eligible for the drawing, survey participants had to complete all of the attitude, interest, and knowledge questions. Participants could, however, opt-out of responding to demographic questions and still be eligible.

The option to participate in the survey was made available to *n*=903, of that *n*=250 consented to participate in the survey, *n*=2 did not consent. Of the *n*=250 consenting participants, *n*=38 participants did not complete the survey and were excluded from analysis, leaving *n*=212 cases for data analysis, an 84% rate of response. Total enrollment for undergraduates at the study site was reported from the 2019 fall census data as 15,275 students, 53.4% of which were female and 46.6% were male (Syracuse University, 2019). For this enrollment size, the survey sample size of *n*=212 is adequate for a 95% confidence interval with a ± 7% margin of error (Qualtrics, 2019). Of the total population sampled *n*=903, the sample size *n*=212 is adequate for a 95% confidence interval with a margin of error of ± 6% (Qualtrics, 2019).

Of the population *n*=212 that provided demographic data, *n*=53 were male, *n*=154 were female, *n*=50 self-reported science as their major, and *n*=157 self reported they were a non-science major. When broken down by gender, *n*=9 males were science majors, *n*=44 males were non-science majors, *n*=41 females were science majors, and *n*=113 females were non-science majors. Non-science females represented the highest number of survey participants and science major males represented the smallest population sampled. Please see Table 1 for participants by gender and major.

Table 1. Survey Participants by Gender and Major.

Gender	**Major**	**N**
Male	Science	9
	Non-science	44
	Total	53
Female	Science	41
	Non-science	113
	Total	154
Total	Science	50
	Non-science	157
	Total	207

Survey Validity and Reliability

To assess the reliability and validity of survey measures, Cronbach's α was calculated for each measure. Then principal component analysis was performed to determine factor loading scores and the degree of measure items to cluster on a construct. Reliability and validity estimates are provided below for the pilot and the survey version used in data collection.

Reliability of the pilot survey.

The likelihood of the test to produce consistent scores from one test session to another is discussed in terms of its reliability. A high reliability suggests that test questions are aligned and assumes that students who answered a given question correctly were more likely to correctly answer other questions (Office of Educational Assessment (OEA), 2019). If questions tend to be unrelated to each other based on who answered correctly, then low reliability would result (OEA, 2019). Reliability coefficients reported as Cronbach's α, range from low (.50 or below) to excellent (.90 and above), with .70-.80 being the range for most classroom tests and is considered good (OEA, 2019).

The first measure of attitude, cause and effect, consisted of eleven questions (α=.899), while the second measure of attitude, risk, consisted of eight questions (α=.863). The two attitude scales had a high level of internal consistency, as determined by Cronbach's α. The measure for topic interest consisted of fourteen questions and had a high level of internal consistency (α=.957). The topic knowledge measure consisted of fourteen questions. The scale had an acceptable level of internal consistency (α=.721). Cronbach's α score could be increased by deleting question four from the knowledge survey, however as this question asks about an important emerging issue within HABs literacy, it was retained in the survey. Based on reliability estimates from the pilot, survey measures are adequate for use in data collection. For all measures, n=65.

Validity of the pilot survey.

A principal component analysis (PCA) was run for the topic interest, attitudes, and topic knowledge measure questions. PCA was selected to test the validity of survey items for several reasons. First, PCA was the validity test used in the studies by Bråten et al. (2009) and Stenseth et al. (2016). In order to compare the results of this study to those studies, the researcher chose to keep in line with their methodology. Second, PCA loading scores can be used to reduce survey items by aiding in deciding the necessary revisions to survey items that should be made from pilot results. Third, PCA can speak to the dimensionality of survey measures. For example, do survey items reflect the intended variables and can they be grouped according to the intended construct?

PCA was used to 'cluster' variables together that all load on the same component to assess the relatedness of the variables for each scale. Indications that variables are not related are if one component only loads on one variable, meaning the variable may not be measuring the same construct as other variables and should be reworded or removed from the survey. Similarly, if variables load on multiple components (cross-loading) or have negative component loadings should be considered in revisions made to the survey. PCA was also used to remove multicollinearity. Following the methodology for PCA outlined by Laerd Statistics (2015), the analysis was conducted:

1. Initial extraction of the components.
2. Determining the number of 'meaningful' components to retain.
3. Rotation to a final solution.
4. Interpreting the rotated solution.
5. Computing component scores or component-based scores.
6. Reporting the results.

The suitability of using PCA for each measure was assessed prior to the analysis. Inspection of the correlation matrix shows that all variables, except the questions from the knowledge measure, had at least one correlation coefficient greater than 0.3 (Laerd Statistics, 2015). Given that the knowledge measure failed this assumption and was not suitable for PCA, item analysis was performed instead. The overall Kaiser-Meyer-Olkin (KMO) measure for the interest measure was 0.869 and 0.861 for attitude; both classified in terms of 'middling' to 'meritorious' according to Kaiser (1974). Bartlett's Test of Sphericity was statistically significant ($p < .0005$), indicating that the data for both measures was likely factorizable (Laerd Statistics, 2015).

Topic interest.

PCA for the interest measure revealed two components that had eigenvalues greater than one and which explained 65.31% and 9.60% of the total variance, respectively. But there was significant cross-loading between a two-component solution (Laerd Statistics, 2015). Hence, a forced factor for one solution was retained. Additionally, a one-component solution met the interpretability criterion (Laerd Statistics, 2015). A one-factor loading solution for interest was used by Bråten et al. (2009); interest survey items were adapted from their instrument. The one component solution explains 64.63% of the total variance. There were strong loadings for each item in the measure, therefore no items were removed, though some were clarified and reworded slightly for the revised version of the survey. For example, “Health effects of harmful algal blooms is a topic that interests me," was reworded to “The health effects of harmful algal blooms is a topic that interests me,” and “I participate in discussions on harmful algal blooms,” was reworded to, “I participate in discussions about harmful algal blooms.” Component loadings and communalities of the rotated solutions are presented in Table 2.

Table 2. Factor Loadings from Principal Component Analysis for a One-Factor Solution for HABs Interest Measure, *N*=65

Item	Factor Loading	Communalities
I'm interested in harmful algal bloom policy	0.878	0.771
I'm interested in issues concerning harmful algal blooms	0.869	0.754
I think that more people should become actively involved in efforts to develop monitoring and communication resources for harmful algal blooms	0.803	0.645
I participate in discussions on harmful algal blooms	0.598	0.358
I am interested in what conditions influence harmful algal blooms	0.889	0.79
I can imagine being a member of an organization that works with natural and environmental issues	0.767	0.588
Health effects of harmful algal blooms is a topic that interests me	0.81	0.656
I am concerned with how I myself can contribute to the reduction of harmful algal blooms	0.833	0.695
I try to convince others that harmful algal blooms may have risks for human health	0.781	0.611
I am interested in issues concerning water pollution	0.772	0.596
I support organizations that work to reduce water pollution	0.676	0.457

Item	Factor Loading	Communalities
I like to keep myself updated on issues concerning harmful algal blooms	0.887	0.788
I am interested in the effects of algal blooms on society	0.9	0.81
In the media more emphasis should be given to social or political issues related to harmful algal blooms	0.788	0.621

Attitudes.

PCA for the attitude measure revealed three components that had eigenvalues greater than one and which explained 45.29%, 25%, and 6% of the total variance, respectively, with significant cross and negative loading factor scores. A two-component solution met the interpretability criterion (Laerd Statistics, 2015). As such, a forced factor solution using two components was retained (Laerd Statistics, 2015). The two-component solution explains 70.29% of the total variance. The interpretation of the data was consistent with the attitude attributes the questionnaire was designed to measure with strong loadings for each item in the measure. Component loadings and communalities of the rotated solutions are presented in Table 3. After PCA of attitude measures, the survey was revised for the fall data collection, items were clarified and reworded and the main changes made to the survey attitude measures can be found in Table 4 below. Based on factor loading scores, all items for attitude were retained in the survey.

Table 3. Factor Loadings from Principal Component Analysis with Varimax Rotation for a Two-Factor Solution for HABs Attitude Measures, *N*=65

Item	**Factor Loading**		**Communalities**
	1	**2**	
I believe that harmful algal blooms can be caused by human activities	0.845		0.732
I believe that runoff from fertilizers can lead to harmful algal blooms	0.867		0.753
I believe that people themselves are responsible for harmful algal blooms	-0.743		0.553
I believe that harmful algal blooms are an issue for the tourist industry	0.882		0.779
I believe research and monitoring for harmful algal blooms are important political issues	0.909		0.827
I believe that harmful algal blooms can have effects on human health	0.908		0.826
I believe that harmful algal blooms can have effects on the marine mammals	0.878		0.777
I believe that harmful algal blooms can affect my daily life	0.707		0.5
I believe harmful algal blooms are a global problem	0.893		0.815
I believe harmful algal blooms are an important economic issue	0.899		0.811
I believe harmful algal blooms are only an issue for people who live near the coast		0.509	0.279

Item	Factor Loading		Communalities
	1	**2**	
I believe it is safe to swim during a harmful algal bloom		0.856	0.746
I believe it is safe to harvest shellfish during a harmful algal bloom		0.885	0.789
I believe it is safe to catch and eat fish during a harmful algal bloom		0.928	0.867
I believe it is safe to eat shellfish from a store/ restaurant during a harmful algal bloom		-0.904	0.821
I believe it is safe to eat fish from a store / restaurant during a harmful algal bloom		-0.883	0.794
I believe skin, eye and respiratory irritations are risks of harmful algal blooms	0.604		0.371

Table 4. Major Question Changes from Pilot to Study Survey

Pilot	Revised	Changes
I believe that harmful algal blooms are a risk to drinking water contamination.	I believe that harmful algal blooms can cause drinking water contamination	These questions were reworded and moved from risk attitude to cause and effect attitude for the revised survey, these items loaded better on cause and effect dimension than risk.
I believe skin, eye and respiratory irritations are risks of harmful algal blooms.	I believe skin, eye and respiratory irritations can be effects of harmful algal blooms.	
I believe harmful algal blooms are only an issue for people who live near the coast	I believe the effects of harmful algal blooms are only a risk for people who live near the coast.	This question was reworded and moved from cause and effect attitude to risk attitude dimension for the revised survey, this item loaded better on the risk dimension than cause and effect.

Topic knowledge.

Instead of PCA, it was more appropriate to assess the validity of the topic knowledge survey items for this study by using item analysis methodology. Item analysis was performed to assess the quality of knowledge measure items by comparing students' item responses to their total test scores and of the measure as a whole and estimating internal consistency (OEA, 2019). This method is valuable for improving items and use in later tests because it can be used to eliminate ambiguous or misleading questions in a single test period, and identify specific areas of content that need greater emphasis or clarity, i.e. misconceptions (OEA, 2019). Misconceptions among students can be indicated by examining frequently selected incorrect alternative answers (OEA, 2019). A basic assumption is that a knowledge survey is measuring a single subject area (HABs) (OEA, 2019). An item will have low discrimination if it is so difficult it is incorrectly answered by most, or if it is easy and most answered correctly (OEA, 2019). Ideal difficulty levels based on discrimination potential for a five-response multiple-choice is 70 (Lord, 1952). Items are classified in terms of difficulty from very easy to very difficult with a range of 41-60 considered average difficulty (OEA, 2019). The ability of an item to differentiate among students on the basis of their knowledge of HABs is referred to as item discrimination. The discrimination index provides an estimate of the extent to which an individual test item is measuring the same topic as the other test items (OEA, 2019). For tests measuring a wide range of topics, the coefficient values would tend to be lower and questions with low or negative discrimination indices should be examined to resolve possible clarity and ambiguity issues due to the wording of the question (OEA, 2019). Items are classified in terms of their ability to discriminate based on the discrimination indices from a very good item (.40 and above) to very poor (.09- .19), with a range of .20-.29 considered fair (OEA, 2019). Item analysis has its imitations as a variety of factors could contribute to low discrimination indices and the data should be viewed as tentative, as it is influenced by the student and instructional characteristics as well as chance errors (Mehrens & Lehmann, 1973). Data from item analysis performed on knowledge questions in the pilot survey was used to decide that all questions should be included in the revised survey based on good item difficulty and discriminate indices. See Table 7 below to compare pilot and study survey item difficulty and discriminate indices.

Reliability of the study survey instrument.

The first measure of attitude, cause and effect, consisted of twelve questions (α=.920), and the second measure of attitude, risk, consisted of seven questions (α=.913). The two attitude scales had a high level of internal consistency, as determined by Cronbach's α. The measure for interest consisted of fourteen questions and had a high level of internal consistency (α=.955). The knowledge measure consisted of fourteen questions. The scale had an acceptable level of internal consistency (α=.696). Cronbach's α score could be increased by deleting question four from the knowledge survey, as was seen from the pilot survey analysis. However, as this question asks about an important emerging issue pertaining to HABs literacy, it was included in analysis. For all measures n=212 with no cases excluded, except for the interest measure, n=211 with one outlier case excluded. Reliability of the survey is consistent with pilot results for all measures.

Test-retest reliability of the knowledge measure was computed using the knowledge scores from non-science major students and two weeks later they were given the retest. The re-test, n=104, had a reliability estimate of $r(102)=.59, p < .001$.

Validity of the study survey instrument.

A principal component analysis (PCA) was run for survey measure questions for each variable; interest, attitude, and knowledge. The suitability of the PCA was assessed prior to the analysis. Inspection of the correlation matrix shows that all variables, except the questions from the knowledge measure, had at least one correlation coefficient greater than 0.3 (Laerd Statistics, 2015). Given that the knowledge measure failed this assumption and was not suitable for PCA, item analysis was performed instead. The overall Kaiser-Meyer-Olkin (KMO) measure for the interest measure was 0.93, and for attitude was 0.877; both classified in terms of 'middling' to 'meritorious' according to Kaiser (1974). Bartlett's Test of Sphericity was statistically significant (*p* < .0005), indicating that the data for both measures was likely factorizable (Laerd Statistics, 2015). The validity of the survey is consistent with the pilot results for all measures.

Topic interest.

Questions for the interest measure for this study come from a Bråten et al. (2009) study where a one-factor solution for interest was also used. PCA for the interest measure revealed two components that had eigenvalues greater than one and which explained 63.931% and 8.882% of the total variance, respectively. However, there was cross-loading between a two-component solution (Laerd Statistics, 2015). A one-component solution met the interpretability criterion, and met with PCA results from the pilot survey (Laerd Statistics, 2015). As such, one component was retained. The one component solution explains 63.931% of the total variance. There was strong loadings for all of the items in the measure. Component loadings and communalities of the rotated solutions are presented in Table 5.

Table 5. Factor Loadings from Principal Component Analysis for a One-Factor Solution for HABs Interest Measure, *N*=212

Item	**Factor Loading**	**Communalities**
I'm interested in harmful algal bloom policy	0.889	0.686
I'm interested in issues concerning harmful algal blooms	0.88	0.757
I think that more people should become actively involved in efforts to develop monitoring and communication resources for harmful algal blooms	0.87	0.624
I participate in discussions on harmful algal blooms	0.859	0.419
I am interested in what conditions influence harmful algal blooms	0.859	0.738
I can imagine being a member of an organization that works with natural and environmental issues	0.842	0.639
Health effects of harmful algal blooms is a topic that interests me	0.829	0.775
I am concerned with how I myself can contribute to the reduction of harmful algal blooms	0.799	0.737
I try to convince others that harmful algal blooms may have risks for human health	0.79	0.523
I am interested in issues concerning water pollution	0.755	0.569
I support organizations that work to reduce water pollution	0.752	0.415

Item	Factor Loading	Communalities
I like to keep myself updated on issues concerning harmful algal blooms	0.723	0.566
I am interested in the effects of algal blooms on society	0.647	0.791
In the media more emphasis should be given to social or political issues related to harmful algal blooms	0.644	0.709

Attitudes.

PCA for the attitude measure revealed four components that had eigenvalues greater than one and which explained 35.092%, 25.345%, 6.013% and 5.813% of the total variance, respectively, with a few cross and negative loading factor scores. A two-component solution met the interpretability criterion and pilot survey PCA results (Laerd Statistics, 2015). As such, a forced factor solution using two components, risk and cause and effect, was retained (Laerd Statistics, 2015). The two-component solution explains 60.437% of the total variance. Component loadings and communalities of the rotated solutions are presented in Table 6.

Table 6. Factor Loadings from Principal Component Analysis with Varimax Rotation for a Two-Factor Solution for HABs Attitude Measures, *N*=212

Item	**Factor Loading**		**Communalities**
	1	**2**	
I believe that harmful algal blooms can be caused by human activities	0.827		0.687
I believe the effects of harmful algal blooms can be seen globally.	0.822		0.637
I believe that harmful algal blooms can have effects on human health.	0.802		0.524
I believe politics can have effects on the research and monitoring of harmful algal blooms.	0.8		0.545
I believe that runoff from fertilizers can lead to harmful algal blooms.	0.785		0.642
I believe harmful algal blooms can have economic effects.	0.741		0.653
I believe harmful algal blooms can have effects on the tourism industry.	0.738		0.609
I believe that harmful algal blooms can have effects on marine mammals.	0.737		0.544
I believe that people are not solely responsible for causing harmful algal blooms.	0.718		0.677
I believe that harmful algal blooms are relevant to my daily life.	0.712		0.555
I believe that harmful algal blooms can cause drinking water contamination.	0.684		0.326

Item	Factor Loading		Communalities
	1	2	
I believe it is safe to harvest shellfish during a harmful algal bloom.		0.886	0.636
I believe it is safe to catch and eat fish during a harmful algal bloom.		0.884	0.758
I believe it is safe to swim during a harmful algal bloom.		0.87	0.786
I believe it is safe to eat shellfish from a store/ restaurant during a harmful algal bloom.		0.834	0.784
I believe it is safe to eat fish from a store / restaurant during a harmful algal bloom.		0.819	0.695
I believe it is safe to travel to a beach during a harmful algal bloom.		0.797	0.673
I believe the effects of harmful algal blooms are only a risk for people who live near the coast.		0.571	0.25

Topic knowledge.

Item analysis was performed to assess the quality of knowledge measure items by comparing students' item responses to their total test scores and of the measure as a whole and estimating internal consistency (Office of Educational Assessment (OEA), 2019). Items are classified in terms of difficulty from very easy to very difficult with a range of 41-60 considered average difficulty (OEA, 2019). The discrimination index is classified from good to poor, a range of .20-.29 is considered fair (OEA, 2019). The frequencies and distribution for each alternative multiple choice answer is reported in terms of the number and percentage of students who selected that response. Please see Table 7 to compare item discriminate and difficulty values between the study survey and pilot. Item analysis results from the fall survey were also used to identify misconceptions and are reported in the results chapter. As question four asks about an emerging issue within HABs and was frequently answered incorrectly in both administrations of the survey, it should be included as an issue that is likely to have associated misconceptions. Please see, Appendix E: Knowledge Survey Items- Percent of Response by Question Options.

Table 7. Knowledge Survey Items: Difficulty and Discriminate Indices by Question

	Pilot				**Survey**			
	Difficulty		**Discrimination**		**Difficulty**		**Discrimination**	
Q1	50.00	Average	0.53	Very good	50.00	Average	0.46	Very good
Q2	64.06	Easy	0.41	Very good	73.11	Easy	0.33	Good
Q3	42.19	Average	0.47	Very good	43.87	Average	0.44	Very good
Q4	10.94	Very difficult	0.18	Poor	3.77	Very Difficult	0.04	Poor
Q5	40.63	Difficult	0.41	Very good	63.21	Easy	0.47	Very good
Q6	50.00	Average	0.76	Very good	56.60	Average	0.68	Very good
Q7	50.00	Average	0.76	Very good	56.13	Average	0.68	Very good
Q8	35.94	Difficult	0.41	Very good	37.26	Difficult	0.37	Good
Q9	46.88	Average	0.71	Very good	56.60	Average	0.81	Very good
Q10	50.00	Average	0.47	Very good	58.49	Average	0.63	Very good
Q11	35.94	Difficult	0.76	Very good	56.60	Average	0.68	Very good
Q12	34.38	Difficult	0.71	Very good	41.51	Average	0.74	Very good
Q13	20.31	Difficult	0.12	Poor	25.94	Difficult	0.32	Good
Q14	25.00	Difficult	0.59	Very good	33.96	Difficult	0.54	Very good

Survey Statistical Analysis Procedures

Once survey validity and reliability were established individual survey items were reduced. Each participant contributed one score for each dimension (topic interest, topic knowledge, risk, and cause and effect) which was based on the mean of individual survey items for that dimension. The results are presented as descriptive statistics which speaks to the participants levels of topic interest, topic knowledge, risk, and cause and effect scores as a whole group.

An analysis of variance (two-way ANOVA) was then conducted to assess the effect major and gender might have on risk, cause and effect, topic interest, and topic knowledge scores. This test is appropriate for use in investigating this study's first research question for two main reasons. The two-way ANOVA is thought of as an extension of the one-way ANOVA and allows the researcher to test the interaction effect between two different independent variables on a dependent variable as well as the interaction effect of one independent variable on a dependent variable (Laerd Statistics, 2017). The two-way ANOVA is used to compare the differences between groups for categorical independent variables and continuous dependent variables, which aligns with the classification of variables for this study (Laerd Statistics, 2017). Thus the two-way ANOVA test will help the researcher investigate, "Are there differences between science majors and non-science majors' topic interest, topic knowledge and attitude levels regarding HABs?" because major, gender, and the interaction can be run as independent variables which can be compared to topic interest, topic knowledge and attitude scores as dependent variables. The mean scores for each group can be compared to see if there are significant differences between science and non-science majors as well as between male and female groups within the science and non-science categories. It is expected based on the prior literature that topic interest, topic knowledge, and attitude scores will be different between science and non-science majors, with science majors expected to have higher cause and effects, topic interest and topic knowledge scores, and more moderate risk attitude scores. There are not expected to be differences between genders and topic interest, topic knowledge or attitude scores. No interaction is expected between major and gender with relation to topic interest, topic knowledge or attitude scores.

To address the second research question, “Do undergraduate students’ interest in and their knowledge about harmful algal blooms predict their attitudes towards HABs?,” two different hierarchical regression analyses were performed using a two-stepwise method with attitude (risk and cause and effect) mean scores as separate dependent variables. First, it is expected that topic knowledge will negatively predict HAB risk attitudes and topic interest will not be a significant predictor, because previous research shows that people may not find HABs to be relevant so may rely more on their topic knowledge rather than their topic interest to form their attitudes. This is also seen when looking at nuclear power risks. It is expected, however, that topic interest and attitudes will depend on the level of topic knowledge, with stronger relationships observed at lower levels than at high levels of topic knowledge, which is inline with the literature regarding risk attitudes regarding nuclear power. Second, topic interest and topic knowledge are expected to be positively related to cause and effect attitudes with topic interest being a better predictor of attitudes with a stronger relationship between topic interest and cause and effect attitudes at higher than at lower levels of topic knowledge. The cause and effect attitudes related to HABs include causes and effects shared with climate change that participants may find more relevant than the risks of HABs.

Part of running a hierarchical multiple regression analysis includes running a Pearson's product-moment correlation reliability estimate. This test is used to assess the relationships between variables by reporting the level of statistical significance of the correlations between the variables and whether or not the variables are positively or negatively correlated (Laerd Statistics, 2018). The Pearson’s product-moment test results determine if a multiple hierarchical regression analysis can be conducted based on the available data. Multiple hierarchical regression is an appropriate statistical test for use in addressing the second research question for several reasons. First, it is the method used by Bråten et al. (2009) and Stenseth et al. (2016) and in order to compare the results of this study to those studies, the researcher chose to keep in line with their methodology. Second, hierarchical multiple regression analysis can be used to predict a dependent variable based on multiple independent variables and speaks to the amount of variation in the dependent variable that can be explained by the addition of variables to the equation (Laerd Statistics, 2015). By using hierarchical regression the researcher is also able to control for the effects of covariates, add or remove predictor variables, and consider the possible causal effects of independent variables in predicting dependent variables (Laerd Statistics, 2015). Hierarchical multiple regression analysis can be run using continuous independent and dependent variables, and independent categorical variables can be re-coded using dummy variables for use in the analysis. Therefore, risk and cause and effect are appropriate dependent variables, while topic interest and topic knowledge meet the requirements for independent variables. The categorical independent variables, major and gender, were re-coded as dummy variables for use in the analysis. Moreover, the results from hierarchical multiple regression tests can be used for subsequent analysis such as simple slope graphs.

In step one of the regression analysis, gender and major were entered as predictors as well as topic interest and topic knowledge centered mean scores. In step two, the interaction between topic interest and topic knowledge was entered in the model as the mean scores of the independent variable called interestXknowledge. Results were then reported by using slope analysis to plot the interactions, following the methods described by Aiken and West (1991), Dawson (2014), and Stenseth et al. (2016), using one standard deviation above and below the mean scores for the predictor on the X-axis as well as for the interacting variable with relation to the mean score for attitudes on the Y-axis. A simple slope analysis was done because plotting the interaction effect allows for a visual interpretation and representation of the relationships that may exist between an independent, dependent, and interaction variable (Dawson, 2014). IBM software, SPSS version 26.0 was used to run the statistical analyses.

The analysis and discussion of the statistical test are described in chapters four and five of this study. Following the pilot, survey administration, and QUANTITATIVE analyses, the qualitative phase was implemented. The methodology for the second phase of the study is described below.

Qualitative Methods

The second phase of this study is qualitative and consists of semi-structured interview questions that were designed to build on survey questions and provide greater insight into participant survey responses. The purpose of the qualitative analysis was to support the bigger focus for this study which was the QUANTITATIVE analysis. Interview participants were selected from survey respondents to develop a more in-depth understanding of the audiences' learner characteristics, prior knowledge and interest, and to make implications for subsequent education and outreach efforts for undergraduate students. Interview response analyses were combined with the analyses and results from part one, in the discussion chapter of this study.

Participants

Survey respondents were sent an email asking for their participation in follow-up interviews related to the HABs survey. An incentive to be entered into an Amazon gift card drawing was offered to encourage the recruitment of interviewees. Participants had a two week window to schedule an interview time according to their schedule. A follow-up email was sent a week after the initial recruitment email. Of the original survey respondents (n=212), n=204 provided an email address and were contacted, of that n=9 responded, and n=6 were interviewed. Three participants could not be interviewed due to having an illness. Of the n=6, broken down by major, n=2 were non-science majors and n=4 were science majors; broken down by gender, n=2 were males and n=4 were females.

Procedure and Setting

Qualitative data collection consisted of a semi-structured interview using predetermined yet open-ended questions, in contrast to structured interviews or using close ended questions that could limit the range of responses to each question (Ayers in Given, 2008). A written interview guide was developed in advance to align with survey content and the research questions (Ayers in Given, 2008), please see Appendix F: Interview Guide. Example questions include, "Have you ever heard of harmful algal blooms, can you explain what they are?", "How interested in the topic are you?", and "How would you like to learn about harmful algal blooms?" The interview guide was not explicitly followed during the interviews and instead participant responses determined the flow of the interview and subsequent probing questions (Ayers in Given, 2008). This design is appropriate to use to answer the third research question, "What do interviews with survey respondents reveal about participant learner characteristics and their recommendations for HABs education and outreach resource design?," because it allowed for the opportunity to obtain qualitative data that provided realism to survey responses (Kempton & Falk, 2000).

Interviews were conducted individually, face-to-face, and lasted between ten and fifteen minutes. Each interview was audio-recorded and fully transcribed verbatim. Transcriptions were grouped and reported by question, then summarized. Due to low participation, the researcher did not code the data using true qualitative research methods, instead took the approach of looking at the data that is qualitative in nature to support the QUANTITATIVE results. This limitation is further discussed in the discussion section of the study. The summaries of participant responses by question were organized and discussed using the following learner characteristics from the CRKM as major guiding themes (a) sources of participants' prior knowledge related to HABs, (b) sources of participants' motivation to engage in the survey and interview, and (c) participants' recommendations for HABs education and outreach resource design. The major themes were then discussed in light of the survey results in chapter V.

Chapter Summary

The goal of this chapter was to outline the mixed-methods used to answer the study research questions. A discussion of each of the QUANTITATIVE and qualitative procedures, study settings and participants, and data collection and analyses described the details of how this study was conducted and who the participants were. A survey that was deemed to have adequate validity and reliability measures and subsequent interviews with participants was used to explore the antecedents that influence misconceptions and explain variation in the variation in levels of topic interest, topic knowledge, and attitudes regarding HABs. The results of the investigation utilizing the methodology described in Chapter III is presented in Chapter IV.

CHAPTER IV: RESULTS

This chapter presents the results of the quantitative statistical analysis and participant interview responses. First, the results of interest, knowledge, and attitude levels for the sample population as a whole are reported. Then each of this study's research questions are addressed in light of statistical findings, followed by a description of the majors themes gleaned from interviews with survey participants. Lastly, a summary of both quantitative and qualitative findings are presented.

Quantitative Analysis

Based on the mean scores of the study variables (topic interest, topic knowledge, risk, cause and effect) for the population sample, the results are described as: topic interest levels are moderate (n=212, m =5.26, SD = 2.20); cause and effect attitude levels are moderate to high (n=212, m =6.92, SD = 1.68); risk attitude levels are low (n=212, m =3.80, SD = 2.06); and topic knowledge levels are low (n=212, m =6.57, SD = 2.95) with the mean score being 46% correct responses on average. Based on skewness the data are fairly symmetrical and have light-tail kurtosis to the left for interest, cause and effect, and knowledge. Risk is moderately skewed with a heavy-tailed kurtosis to the right, see Table 8.

Table 8. Descriptive Statistics for Study Variables, *N*=212

Variable	Mean		Std. Deviation	Variance	Skewness		Kurtosis	
	Statistic	Std. Error			Statistic	Std. Error	Statistic	Std. Error
Interest	5.27	0.15	2.21	4.88	0.17	0.17	-0.52	0.33
Cause_Effect	6.93	0.12	1.68	2.84	-0.15	0.17	-0.38	0.33
Risk	3.80	0.14	2.06	4.26	1.06	0.17	1.19	0.33
Knowledge	6.57	0.20	2.96	8.76	0.00	0.17	-0.89	0.33
InterestX knowledge	0.31	0.46	6.67	44.52	-0.61	0.17	3.60	0.33

Misconceptions

Misconceptions were identified for risk, and cause and effect by looking at the mean score, standard deviation, and variance for individual survey items. Cause and effect items that had a low mean score, below 6, were selected as misconceptions. For risk, items that had a low mean score (below 5) but should have had a higher mean score (above 5) were selected. Knowledge misconceptions were identified by questions that had an incorrect response rate greater than 40%, meaning that for questions to not be considered as misconceptions it was answered correctly by 60% of respondents. See Table 9, for misconceptions. The analysis of the misconceptions listed will be discussed in chapter five of this study.

Table 9. Misconceptions Related to Risk, Cause and Effect, and Topic Knowledge

Misconceptions	Mean	Std Deviation	Variance
Cause and Effect Misconceptions (below mean)			
I believe that harmful algal blooms can have effects on my daily life.	5.97	2.48	6.13
I believe harmful algal blooms can have economic effects.	6.44	2.32	5.38
I believe skin, eye and respiratory irritations can be effects of harmful algal blooms.	5.7	2.74	7.53
Risk Misconceptions (below mean)			
I believe it is safe to swim during a harmful algal bloom	3.73	2.66	7.1
I believe it is safe to harvest shellfish during a harmful algal bloom	3.68	2.68	7.17
I believe it is safe to eat shellfish from a store/ restaurant during a harmful algal bloom	3.5	2.39	5.71
I believe it is safe to eat fish from a store / restaurant during a harmful algal bloom	3.61	2.48	6.17
Knowledge Misconceptions	**Incorrect Response Greater than 40%**		
Q1 An algal bloom is composed of *colonies of algae or bacteria that grow out of control.*	49%		
Q3 A harmful algal bloom is *rapid and uncontrolled growth of algae that can sometimes secrete toxins.*	56.31%		
Q4 Plastics *can absorb toxins produced by harmful algal blooms.*	95.95%		
Q6 Harmful algal blooms are caused by *a combination of factors that depend on the type of bloom.*	43.32%		
Q7 Algal blooms *are increasing in frequency and duration.*	43.32%		

Knowledge Misconceptions	Incorrect Response Greater than 40%
Q8 Phytoplankton *are single or multicellular photosynthetic organisms.*	62.67%
Q9 Algal blooms *can have a variety of colors or none at all.*	43.32%
Q10 Harmful algal blooms *can increase because of human activity.*	41.47%
Q11 Algae *are food for many organisms.*	43.40%
Q12 Algae blooms *sometimes produce a toxin that becomes harmful when it reaches a certain concentration.*	58.49%
Q13 An algal bloom *in freshwater could affect a marine environment by being washed downstream.*	74.06%
Q14 Possible negative effects of harmful algal *blooms include a decrease in dissolved oxygen and increase in carbon dioxide in the water.*	66.04%

Summary of Descriptive Statistics Results and Misconceptions

Based on the sample population's mean scores, their interest levels were moderate, they held moderate to high beliefs in the cause and effects of HABs, low risk attitude levels (meaning HABs are seen as a risk and unsafe), and had low topic knowledge levels in general. Undergraduates in this study had several misconceptions associated with their topic knowledge, 10 out of the 14 questions on the knowledge survey measure had an incorrect response rate of greater than 40%. The results of this study indicated that participants had several misconceptions related to their beliefs about the risk towards HABs. For example, participants accurately believed harvesting and fishing during HABs to be a risk, but they inaccurately believed buying fish and shellfish from a restaurant or supermarket is just as much of a risk. Participants had few misconceptions related to their beliefs about the causes and effects, the misconception that stands out the most is that participants did not believe HABs to have effects on their everyday lives.

ANOVA Results

To answer the first research question, "Are there differences between science majors and non-science majors' interest, knowledge and attitude levels regarding HABs?," a two-way ANOVA was conducted to examine the effects of gender and major on interest, knowledge, risk, and cause and effect scores. Descriptive statistics for all variables, presented in Tables 10.1 to 10.4, followed by cluster bar mean graphs for each variable presented in Figure 2.1 to 2.4.

Table 10.1 Descriptive Statistics for Topic Interest

Gender	**Major**	**Mean**	**Std. Deviation**	**N**
Male	Science	6.18	2.02	9
	Non-science	4.86	2.06	44
	Total	5.08	2.09	53
Female	Science	5.92	1.93	41
	Non-science	5.14	2.37	113
	Total	5.35	2.28	154
Total	Science	5.96	1.93	50
	Non-science	5.06	2.28	157
	Total	5.28	2.23	207

Table 10.2 Descriptive Statistics for Cause and Effect

Gender	Major	Mean	Std. Deviation	N
Male	Science	7.31	1.92	9
	Non-science	6.45	1.34	44
	Total	6.59	1.47	53
Female	Science	7.26	1.46	41
	Non-science	6.99	1.85	113
	Total	7.06	1.75	154
Total	Science	7.27	1.53	50
	Non-science	6.84	1.73	157
	Total	6.94	1.69	207

Table 10.3 Descriptive Statistics for Risk

Gender	Major	Mean	Std. Deviation	N
Male	Science	4.16	2.38	9
	Non-science	3.54	1.54	44
	Total	3.64	1.70	53
Female	Science	3.52	1.92	41
	Non-science	3.98	2.29	113
	Total	3.86	2.20	154
Total	Science	3.63	2.00	50
	Non-science	3.86	2.11	157
	Total	3.80	2.08	207

Table 10.4 Descriptive Statistics for Topic Knowledge

Gender	Major	Mean	Std. Deviation	N
Male	Science	9.22	3.07	9
	Non-science	6.00	2.90	44
	Total	6.55	3.15	53
Female	Science	8.10	2.72	41
	Non-science	6.09	2.78	113
	Total	6.62	2.89	154
Total	Science	8.30	2.79	50
	Non-science	6.06	2.80	157
	Total	6.60	2.95	207

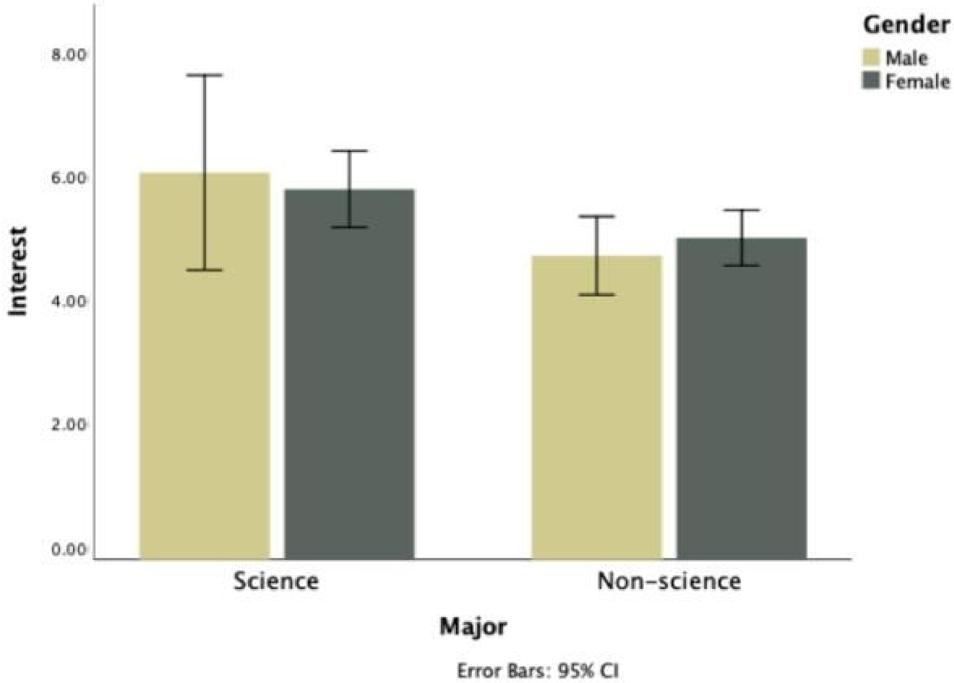

Figure 2.1 Cluster Bar Mean for Topic Interest, by Major and Gender

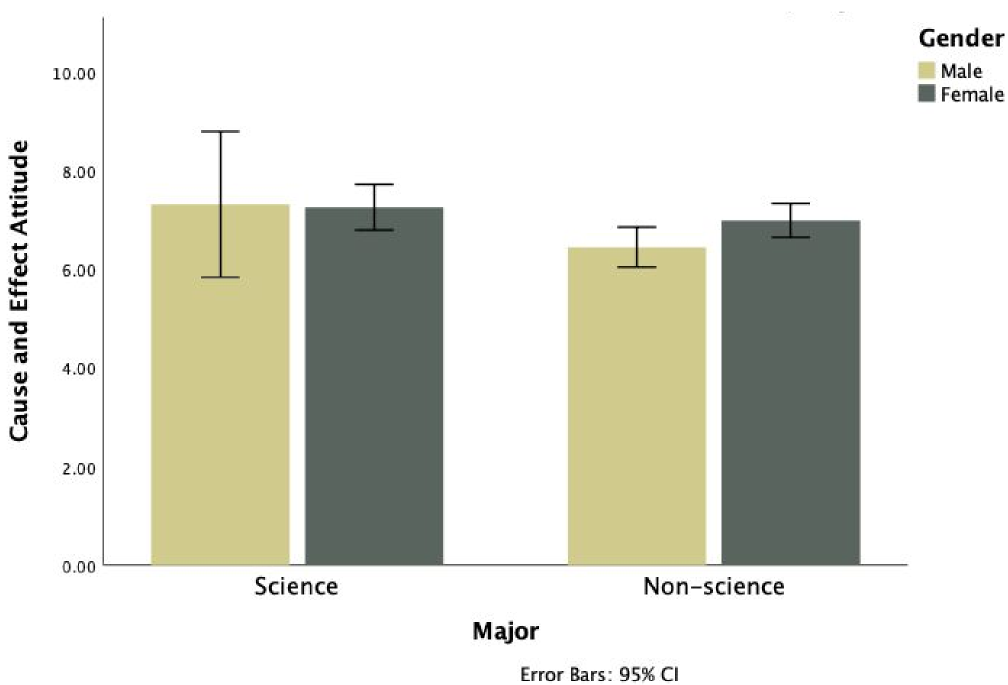

Figure 2.2 Cluster Bar Mean for Cause and Effect, by Major and Gender

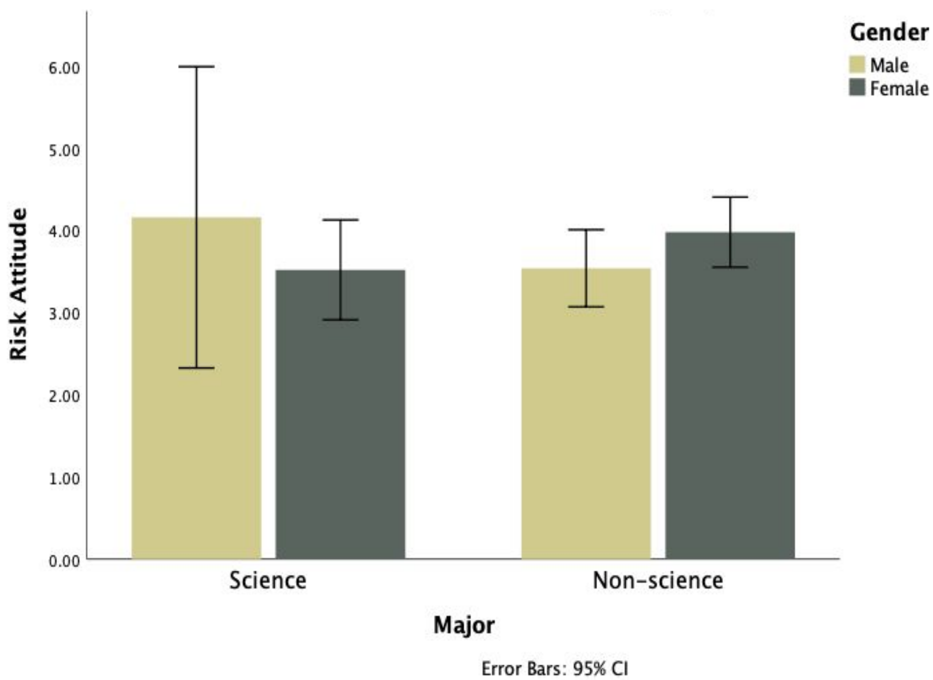

Figure 2.3 Cluster Bar Mean for Risk, by Major and Gender

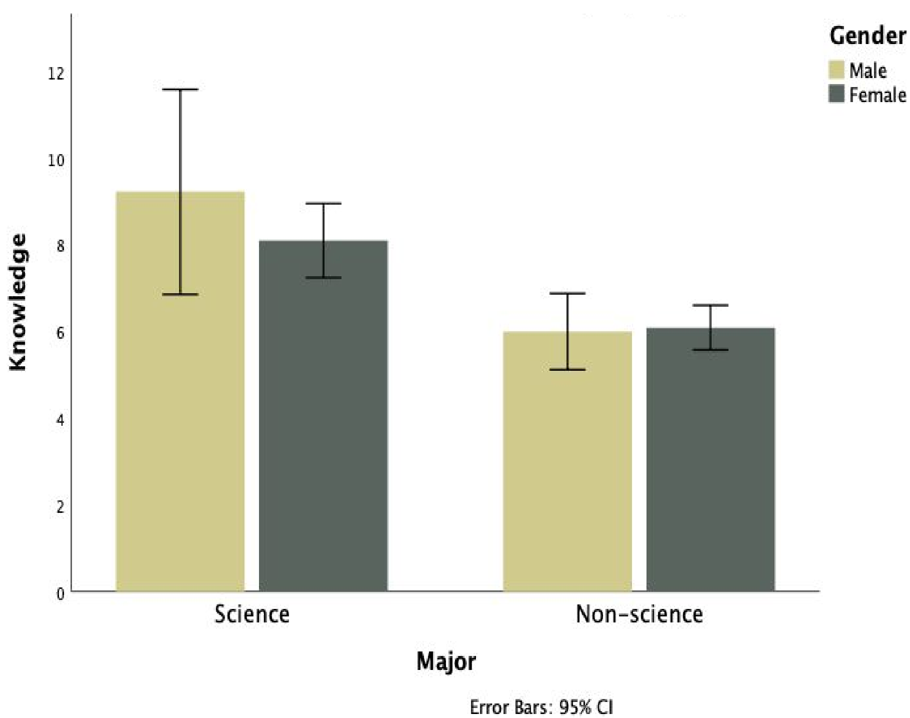

Figure 2.4 Cluster Bar Mean for Topic Knowledge, by Major and Gender

Residual analysis was performed to test for the assumptions of the two-way ANOVA (Laerd Statistics, 2017). There were no outliers, as assessed by inspection of a boxplot (Laerd Statistics, 2017). Data was normally distributed, as assessed by Shapiro-Wilk's test ($p > .05$) (Laerd Statistics, 2017). There was homogeneity of variances, as assessed by Levene's test for equality of variances $p > .05$, $p =.183$ for interest, risk $p=.083$, knowledge $p=.753$ (Laerd Statistics, 2017). The assumption of homogeneity of variances was violated, as assessed by Levene's test for equality of variances, for cause and effect $p < .05$, $p = .01$ (Laerd Statistics, 2017). The ANOVA was run despite the violation of assumption as advised by Laerd Statistics (2017) following Jaccard (1998), “there is normality and the ratio of the largest group variance to the smallest group variance is less than 3, run the two-way ANOVA anyway because it is somewhat robust to heterogeneity of variance in these circumstances,” (Laerd Statistics, 2017 p. 10). The results of the ANOVA are reported below. Tables 11.1 to 11.4 provide the two-way ANOVA results for the test of between subject effects for each variable.

There was not a statistically significant interaction between gender and major for the variables cause and effect score $F(1, 203) = .768$, $p = .382$, partial $\eta^2 = .004$; risk score $F(1, 203) = 1.602$, $p = .207$, partial $\eta^2 = .008$; interest score $F(1,203) = .372$, $p=.543$, partial $\eta^2 = .002$; or knowledge score $F(1, 203) = 1.120$, $p = .291$, partial $\eta^2 = .005$.

Table 11.1 Two-Way ANOVA Results for Test of Between Subject Effects for Topic Interest

Variable	**Type III Sum of Squares**	***df***	**Mean Square**	***F***	**Sig.**	**Partial Eta Squared**
Corrected Model	33.958[a]	3	11.32	2.32	0.077	0.03
Intercept	2922.70	1	2922.70	598.55	0.000	0.75
Gender	0.00	1	0.00	0.00	0.984	0.00
Major	26.39	1	26.39	5.40	0.021*	0.03
Gender * Major	1.82	1	1.82	0.37	0.543	0.00
Error	991.25	203	4.88			
Total	6796.05	207				
Corrected Total	1025.20	206				

Note. *. Significant at the .05 level.
a. R Squared = .033 (Adjusted R Squared = .019)

Table 11.2 Two-Way ANOVA Results for Test of Between Subject Effects for Cause and Effect

Variable	**Type III Sum of Squares**	***df***	**Mean Square**	***F***	**Sig.**	**Partial Eta Squared**
Corrected Model	16.34[a]	3	5.45	1.93	0.126	0.03
Intercept	4695.19	1	4695.19	1662.02	0.000	0.89
Gender	1.41	1	1.41	0.50	0.481	0.00
Major	7.69	1	7.69	2.72	0.101	0.01
Gender * Major	2.17	1	2.17	0.77	0.382	0.00
Error	573.47	203	2.82			
Total	10564.35	207				
Corrected Total	589.82	206				

Note. a. R Squared = .028 (Adjusted R Squared = .013)

Table 11.3 Two-Way ANOVA Results for Test of Between Subject Effects for Risk

Variable	**Type III Sum of Squares**	***df***	**Mean Square**	***F***	**Sig.**	**Partial Eta Squared**
Corrected Model	10.99[a]	3	3.66	0.84	0.472	0.01
Intercept	1381.98	1	1381.98	317.73	0.000	0.61
Gender	0.24	1	0.24	0.06	0.815	0.00
Major	0.15	1	0.15	0.04	0.851	0.00
Gender * Major	6.97	1	6.97	1.60	0.207	0.01
Error	882.95	203	4.35			
Total	3886.06	207				
Corrected Total	893.94	206				

Note. a. R Squared = .012 (Adjusted R Squared = -.002)

Table 11.4 Two-Way ANOVA Results for Test of Between Subject Effects for Topic Knowledge

Variable	Type III Sum of Squares	*df*	Mean Square	*F*	Sig.	Partial Eta Squared
Corrected Model	199.23[a]	3	66.41	8.45	0.000	0.11
Intercept	5176.30	1	5176.30	658.27	0.000	0.76
Gender	6.43	1	6.43	0.82	0.367	0.00
Major	163.79	1	163.79	20.83	0.000*	0.09
Gender * Major	8.81	1	8.81	1.12	0.291	0.01
Error	1596.28	203	7.86			
Total	10823.00	207				
Corrected Total	1795.52	206				

Note. *. Significant at the .05 level.
a. R Squared = .111 (Adjusted R Squared = .098)

A non-statistically significant interaction, however, does not mean that an interaction effect does not exist in the population (Faraway, 2015; Fox, 2008; Searle, 2006). Faraway (2015) states that it is still justifiable to run simple main effects even when the interaction effect is not statistically significant. By running the analysis of the simple main effects using Type III sums of squares instead of as separate one-way ANOVAs, the overall error term of the two-way ANOVA is used for these simple main effects rather than an error term specific to each (Laerd Statistics, 2017). This method is safer and considered to provide valid results even if there is a violation of the principle of marginality (Fox, 2008; Howell, 2010; Jaccard, 1998; Kutner et al., 2005; Maxwell & Delaney, 2004; Laerd Statistics, 2017; Stevens; 2009). Interpreting the results is the same as if there was a statistically significant interaction (Laerd Statistics, 2017). Therefore an analysis of the simple main effects for gender and for major was run (Laerd Statistics, 2017). As there were unequal sample sizes between groups, the Tukey-Kramer post hoc test method was used to calculate the estimated standard deviation for each pairwise comparison, this method has been shown to be conservative (Hayter, 1984; Laerd Statistics, 2017). Data are mean ± standard deviation unless otherwise stated. All pairwise comparisons were run for each simple main effect with reported 95% confidence intervals and *p*-values Bonferroni-adjusted within each simple main effect to account for uneven case sizes (Laerd Statistics, 2017).

The simple main effect of gender on mean scores for test between subjects revealed there was not a statistically significant difference between males and females for risk, cause and effect, knowledge, interest, meaning the simple main effect of gender on mean was not statistically significant; risk, $F(1, 203) = .055$, $p = .815$, partial $\eta^2 = .000$; cause and effect, $F(1, 203) = .498$, $p = .481$, partial $\eta^2 = .002$; interest, $F(1, 203) = .000$, $p = .984$, partial $\eta^2 = .000$; knowledge, $F(1, 203) = .817$, $p = .367$, partial $\eta^2 = .004$. The simple main effect of gender on mean scores for science majors; risk, $F(1, 203) = .694$, $p = .406$, partial $\eta^2 = .003$; cause and effect, $F(1, 203) = .009$, $p = .924$, partial $\eta^2 = .000$; interest- $F(1, 203) = .107$, $p = .744$, partial $\eta^2 = .001$; knowledge- $F(1, 203) = 1.187$, $p = .277$, partial $\eta^2 = .006$. The simple main effect of gender on mean scores for non-science majors; risk, $F(1, 203) = 1.407$, $p = .237$, partial $\eta^2 = .007$; cause and effect, $F(1, 203) = 3.311$, $p = .070$, partial $\eta^2 = .016$; interest- $F(1, 203) = .526$, p=.469, partial $\eta^2 = .003$; knowledge- $F(1, 203) = .32$, $p = .859$, partial $\eta^2 = .000$.

Tables 12.1 to 12.4 present the two-way ANOVA results for the pairwise comparison tests for each variable. Pairwise comparison revealed that major did not have a significant effect on risk or cause and effect, but did have an effect on interest and knowledge between science and non-science majors. The simple main effect of major on mean scores; risk, $F(1, 203) = .035$, $p = .851$, partial $\eta^2 = .000$; cause and effect, $F(1, 203) = 2.722$, $p = .101$, partial $\eta^2 = .013$; interest, $F(1, 203) = 5.405$, $p = .021$, partial $\eta^2 = .026$, a small effect; knowledge, $F(1, 203) = 20.83$, $p = .000$, partial $\eta^2 = .093$, a medium effect.

The simple main effect was statistically significant; interest, non majors (n=159, m =5.05, SD = 2.27) and (n= 50, m=5.96, SD = 1.929) higher for majors, a mean difference of .91, SE=0.15, 95% CI [4.96, 5.57], F(1, 203 = 5.40, p = .011, partial $\eta^2 = .026$; knowledge, non majors (n=159 , m=6.09, SD = 2.802) and (n=50 , m=8.30, SD = 2.787) higher for majors, a mean difference of 2.21, SE=0.2, 95% CI [6.22, 7.02], $F(1, 203) = 20.830$, $p = .000$, partial $\eta^2 = .093$.

The simple main effect of major on mean scores for females was only statistically significant for knowledge, although there was a difference between science and non-science major interest levels there was not a statistical difference seen when non-science and science females are compared; interest, $F(1, 203) = 3.696$, $p = .056$, partial $\eta^2 = .018$; knowledge, $F(1, 203) = 15.442$, $p = .000$, partial $\eta^2 = .071$, for female non majors (n=113, m =6.088, SD = 2.27) and (n= 41, m=8.098, SD = 2.719) higher knowledge for female majors, a mean difference of 2.01, SE=.51, 95% CI [1.00, 3.01].

The simple main effect of major on mean scores for males was similar to females, although there was a difference between science and non-science major interest levels there was not a statistical difference seen when non-science and science males are compared and only the effect of major on knowledge remained significant; interest, $F(1, 203) = 2.688$, $p = .103$, partial $\eta^2 = .018$; knowledge, $F(1, 203) = 9.865$, $p = .002$, partial $\eta^2 = .046$, for male non majors (*n*=44 , *m*=6.00, *SD* = 2.901) and (*n*=9 , *m*=9.22, *SD* = 3.073) higher for male majors, a mean difference of 3.22, *SE*=1.06, 95% *CI* [1.19, 5.24],

An interaction contrast was run that compared the difference between the differences in non-science and science major males and non-science and science major female students' interest and knowledge scores. The difference between the difference was not significant; interest, means difference of 0.551, 95% *CI* [-1.230, 2.332], *p*=.543; knowledge, mean difference of 1.213, 95% *CI* [-1.047, 3.473], *p*=.291.

Table 12.1 Two-Way ANOVA Results for Pairwise Comparison for Topic Interest

Major	Gender		Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
						Lower Bound	Upper Bound
Science	Male	Female	0.27	0.81	0.744	-1.34	1.87
	Female	Male	-0.27	0.81	0.744	-1.87	1.34
Non-science	Male	Female	-0.28	0.39	0.469	-1.06	0.49
	Female	Male	0.28	0.39	0.469	-0.49	1.06

Note. Based on estimated marginal means

a. Adjustment for multiple comparisons: Bonferroni.

Table 12.2 Two-Way ANOVA Results for Pairwise Comparison for Cause and Effect

Major	**Gender**		**Mean Difference (I-J)**	**Std. Error**	**Sig.**[a]	**95% Confidence Interval for Difference**[a]	
						Lower Bound	**Upper Bound**
Science	Male	Female	0.06	0.62	0.924	-1.16	1.28
	Female	Male	-0.06	0.62	0.924	-1.28	1.16
Non-science	Male	Female	-0.54	0.30	0.070	-1.13	0.05
	Female	Male	0.54	0.30	0.070	-0.05	1.13

Note. Based on estimated marginal means

a. Adjustment for multiple comparisons: Bonferroni.

Table 12.3 Two-Way ANOVA Results for Pairwise Comparison for Risk

Major	**Gender**		**Mean Difference (I-J)**	**Std. Error**	**Sig.**[a]	**95% Confidence Interval for Difference**[a]	
						Lower Bound	**Upper Bound**
Science	Male	Female	0.64	0.77	0.406	-0.87	2.15
	Female	Male	-0.64	0.77	0.406	-2.15	0.87
Non-science	Male	Female	-0.44	0.37	0.237	-1.17	0.29
	Female	Male	0.44	0.37	0.237	-0.29	1.17

Note. Based on estimated marginal means

a. Adjustment for multiple comparisons: Bonferroni.

Table 12.4 Two-Way ANOVA Results for Pairwise Comparison for Topic Knowledge

Major	Gender		Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
						Lower Bound	Upper Bound
Science	Male	Female	1.12	1.03	0.277	-0.91	3.16
	Female	Male	-1.12	1.03	0.277	-3.16	0.91
Non-science	Male	Female	-0.09	0.50	0.859	-1.07	0.89
	Female	Male	0.09	0.50	0.859	-0.89	1.07

Note. Based on estimated marginal means

a. Adjustment for multiple comparisons: Bonferroni.

Summary of Two-way ANOVA Analysis

Gender and major did not statistically significantly interact together to influence risk, cause and effect, topic interest, or topic knowledge scores. Gender did not have an effect on risk, cause and effect, topic interest, or topic knowledge, there was no significant difference in mean scores between males and females. Gender did not have a significant effect on mean scores between science and non-science majors. Major had a statistically significant effect on mean topic interest and topic knowledge scores. Science majors had higher topic interest and topic knowledge scores, however major did not have an effect on risk or cause and effect mean scores. Major emerged as a better predictor of topic interest and topic knowledge than gender. To answer the first research question, “Are there differences between science and non-science majors topic interest, topic knowledge, and attitudes towards HABs?,” there is a slight difference between science majors and non-science majors topic interest and topic knowledge mean scores, however there was no difference observed in their attitude scores.

Regression Analysis Results

To answer the second research question, “Do topic interest and topic knowledge predict attitudes regarding HABs?,” correlation, multiple regression, and simple slope analysis were conducted.

Correlation analysis.

A Pearson's product-moment correlation reliability estimate was run to assess the relationship between the two attitude variables, risk, and cause and effect and the independent variables knowledge, interest, gender, and major. The assumption of normality for 'causes and effects' and ‘risk’ scores was satisfied for all group combinations of gender and major level, as assessed by visual inspection of their histograms (Laerd Statistics, 2018). As well as being normally distributed, visual analysis of the p-p plots showed the relationship to be linear with all variables and there were no outliers (Laerd Statistics, 2018). Intercorrelations are presented in Table 13.

Table 13. Zero-order Correlations for Study Variables

Variable	Risk	Cause_Effect	Topic Knowledge	Topic Interest
Risk	-			
Cause_Effect	-0.019	-		
Topic Knowledge	-.443**	.230**	-	
Topic Interest	0.129	.589**	0.047	-
InterestXknowledge	-.393**	-0.066	0.109	-0.072

Note. **. Correlation is significant at the 0.01 level (2-tailed).

The analysis found no significant correlation between risk and a) cause and effect, b) gender, c) major, d) topic interest. Correlation analysis did find a moderately statistically significant negative correlation between risk and topic knowledge, $r(210)=-.44$, $p < .001$, with knowledge explaining 19% of the variation in risk.

Similarly, for the variable cause and effect, analysis found no significant correlation to a) gender and b) major. However, a strong statistically significant positive correlation between cause and effect and topic interest, $r(210)=.58$, $p < .001$, with interest explaining 33% of the variation in cause and effect, as well as a moderate statistically significant positive correlation between cause and effect and topic knowledge, $r(210)=.23$, $p < .001$, with knowledge explaining 5% of the variation in cause and effect, was found.

For topic interest, there was no significant correlation with gender. Major, however, has a small statistically significant negative correlation with topic interest, $r(210)=-.17$, $p < .05$ with major explaining 2% of the variation in topic interest.

No significant correlation was found between topic knowledge and gender. Major had a moderate statistically significant negative correlation with topic knowledge, $r(210)=-.32$, $p<.000$, with major explaining 10% of the variation in knowledge. Positive correlation between HABs interest and HABs knowledge, but the strength of the association is weak, $r(210)=.047$, $p<.493$.

Correlation analysis summary.

Correlation analysis revealed a moderately statistically significant negative correlation between risk and topic knowledge, with topic knowledge explaining 19% of the variation in risk. A strong statistically significant positive correlation between cause and effect and topic interest, with topic interest explaining 33% of the variation in cause and effect. Additionally, a moderate statistically significant positive correlation between cause and effect and topic knowledge, with topic knowledge explaining 5% of the variation in cause and effect, was found. The analysis found no significant correlation between risk and a) cause and effect, b) gender, c) major, d) topic interest. Similarly, for the variable cause and effect, analysis found no significant correlation to a) gender and b) major. For topic interest, there was no significant correlation with gender. Major, however, has a small statistically significant negative correlation with topic interest, major explaining 2% of the variation in topic interest. No significant correlation was found between topic knowledge and gender. Major had a moderate statistically significant negative correlation with topic knowledge, with major explaining 10% of the variation in knowledge. Positive correlation between HABs interest and HABs knowledge, was found but the strength of the association is weak.

Hierarchical multiple regression.

Two separate hierarchical multiple regression for risk, and cause and effect as dependent variables the model was run; step 1: gender, major, interest, and knowledge, step 2: gender, major, interest, knowledge, and interestXknowledge (interaction term). To prevent multicollinearity, before the regression analysis, the interaction variable was created by first centering the mean scores for interest and knowledge, and then multiplying the two centered means together to create a new variable (Cohen, Cohen, West, & Aiken, 2003). Attitude scales and the interaction term were left uncentered (Cohen et al., 2003). For both regression analysis, there was linearity as assessed by partial regression plots and a plot of studentized residuals against the predicted values (Laerd Statistics, 2015). There was an independence of residuals, as assessed by a Durbin-Watson statistic of 1.834 for cause and effect, and 2.115 for risk, a value close to two is considered acceptable (Laerd Statistics, 2015). Homoscedasticity was established, as assessed by visual inspection of a plot of studentized residuals versus unstandardized predicted values (Laerd Statistics, 2015). Looking at the tolerance values reveal no values lower than 0.3, indicating no issues with collinearity (Hair, Black, Babin, & Anderson, 2014). There were no studentized deleted residuals greater than ±3 standard deviations. Following the general rule of thumb that leverage values less than 0.2 as safe, values are below 0.2 (Huber, 1981). There are no Cook’s distance values above 1 to indicate the need to record highly influential points (Cook & Weisberg, 1982). The Q-Q Plots were used to check for the assumption of normality, neither regression violated this assumption (Laerd Statistics, 2015). Following the regression analysis the interaction between topic interest and topic knowledge was graphed using the procedures described by Aiken, West, and Reno (1991), Dawson (2014), and Stenseth et al (2016) and a tool provided by Dawson (n.d.).

Risk.

Can undergraduate students' interest in and their knowledge about harmful algal blooms (HABs), independently and interactively, predict their attitudes towards risks associated with HABs? The addition of the interaction term to the prediction of risk attitude led to a statistically significant increase in R^2 of 0.123, $F(1, 201)= 38.108$, $p < .001$. The full model gender, major, knowledge, interest, and the interaction term to predict risk attitudes was statistically significant, $R^2 =.351$, $F(5, 201)=21.720$, $p < .001$, adjusted $R^2 =0.335$. The interaction term (β=-.111, p=0.000), knowledge (β=-.320, $p < .05$), and major (β=-.679, $p < .05$) were unique predictors of risk. Interest was a unique predictor in step 1 of the model (β=.128, $p < .05$) but was not in the final model. Gender was not a unique predictor of risk attitude (β=.165, p>.262). Table 14 presents the regression model summary, Table 15 provides the results of the regression analysis.

Table 14. Regression Model Summary for Risk Attitudes

	Model	Sum of Squares	df	Mean Square	F	Sig.
1	Regression	203.54	4	50.89	14.89	.000[b]
	Residual	690.40	202	3.42		
	Total	893.94	206			
2	Regression	313.57	5	62.71	21.72	.000[c]
	Residual	580.37	201	2.89		
	Total	893.94	206			

Note.

b. Predictors: (Constant), Interest, Gender, Knowledge, Major

c. Predictors: (Constant), Interest, Gender, Knowledge, Major, InterestXKnowledge

Table 15. Results of Hierarchical Regression Analysis for Predicting Risk Attitudes

		Unstandardized Coefficients		Standardized Coefficients			95.0% Confidence Interval for B	
	Model	B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound
1	(Constant)	3.99	0.37		10.85	0.000	3.27	4.72
	Gender	0.17	0.30	0.03	0.56	0.578	-0.42	0.75
	Major	-0.40	0.32	-0.08	-1.24	0.215	-1.04	0.24
	Knowledge	-0.34	0.05	-0.48	-7.32	0.000**	-0.43	-0.25
	Interest	0.13	0.06	0.14	2.18	0.031*	0.01	0.24
2	(Constant)	4.24	0.34		12.45	0.000	3.57	4.91
	Gender	0.16	0.27	0.03	0.60	0.548	-0.37	0.70
	Major	-0.68	0.30	-0.14	-2.26	0.025*	-1.27	-0.09
	Knowledge	-0.32	0.04	-0.45	-7.53	0.000**	-0.40	-0.24
	Interest	0.09	0.05	0.10	1.69	0.093	-0.02	0.20
	InterestXKnowledge	-0.11	0.02	-0.36	-6.17	0.000**	-0.15	-0.08

*Note. **. Correlation is significant at the 0.01 level (2-tailed).*

**. Correlation is significant at the 0.05 level (1-tailed).*

Simple slope analysis.

The interaction graph between topic interest and topic knowledge indicates that the relationship between topic interest and attitude towards HABs risks depends on students' level of topic knowledge with a stronger relationship observed at lower levels than at higher levels of topic knowledge. A simple slope analysis showed that at a level of one standard deviation below the mean for the topic knowledge variable and risk, $b=.419$, $t=7.658$, $p < .001$, and one standard deviation above, $b=-.235$, $t=-4.299$, $p < .001$, accordingly Cohen (1988) states that 32% explained variance (f^2=-.092) is considered medium effect in multiple regression analysis. The results of the slope analysis are shown in Figure 3.

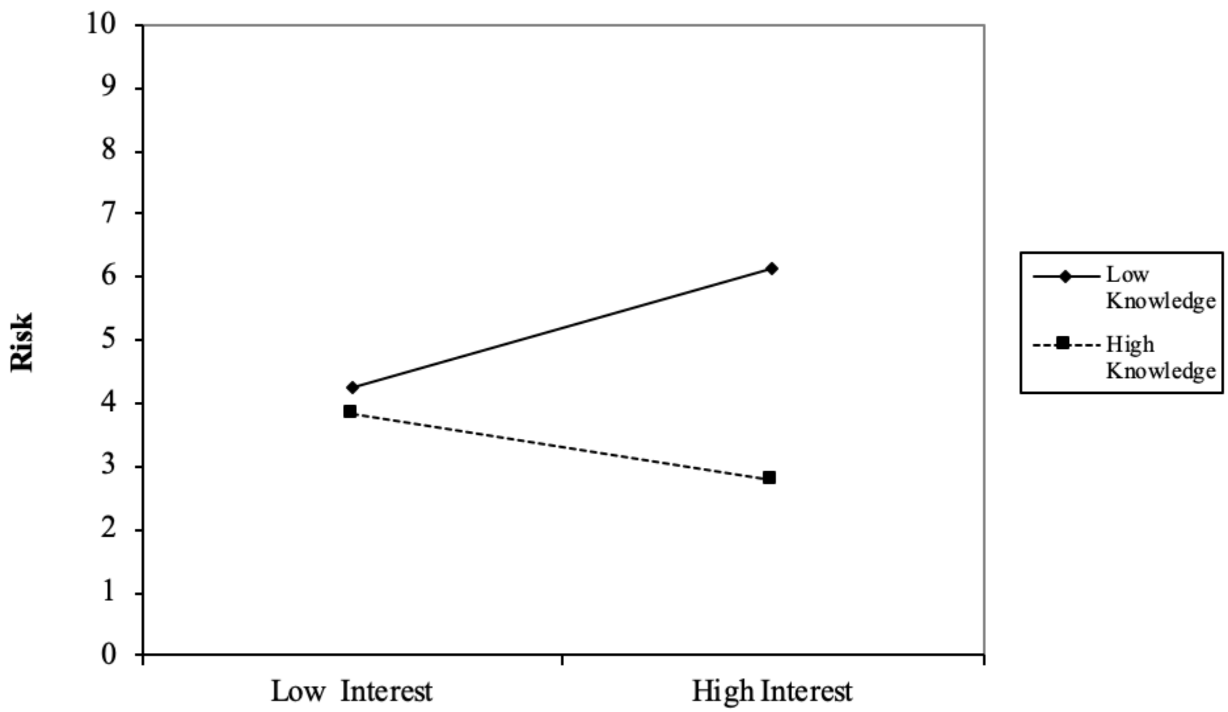

Figure 3. Interactions Between Topic Interest and Topic Knowledge for Risk Attitudes

Cause and effect.

Can undergraduate students' interest in and their knowledge about harmful algal blooms (HABs), independently and interactively, predict their attitudes towards the causes and effects of HABs? The addition of the interaction term to the prediction of cause and effect attitude leads to a negligible decrease in R^2 of .002, $F(1, 201)= .665$. However, the full model gender, major, knowledge, interest, and the interaction term to predict the attitude dimension cause and effect was statistically significant, $R^2 =.406$, $F(5,201)=27.434$, $p < .001$, adjusted $R^2 =.406$. Interest ($\beta=.441$, $p < .05$), and knowledge ($\beta=.135$, $p < .05$) were unique predictors of cause and effects. Gender was not a unique predictor of cause and effect attitude, ($\beta=.368$, $p>.042$), neither was major ($\beta=.278$, $p>.060$) or the interaction term ($\beta=-.011$, $p>.147$). Table 16 presents the regression model summary, Table 17 provides the results of the regression analysis.

Table 16. Regression Model Summary for Cause and Effect Attitudes

Model		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
1	Regression	238.08	4	59.52	34.18	.000b
	Residual	351.73	202	1.74		
	Total	589.82	206			
2	Regression	239.24	5	47.85	27.43	.000c
	Residual	350.57	201	1.74		
	Total	589.82	206			

Note. a. Dependent Variable: Cause and Effect

b. Predictors: (Constant), Interest, Gender, Knowledge, Major

c. Predictors: (Constant), Interest, Gender, Knowledge, Major, InterestXKnowledge

Table 17. Results of Hierarchical Regression Analysis for Predicting Cause and Effect Attitudes

		Unstandardized Coefficients		Standardized Coefficients			95.0% Confidence Interval for B	
	Model	**B**	**Std. Error**	**Beta**	**t**	**Sig.**	**Lower Bound**	**Upper Bound**
1	(Constant)	6.42	0.26		24.45	0.000	5.91	6.94
	Gender	0.37	0.21	0.10	1.74	0.083	-0.05	0.78
	Major	0.31	0.23	0.08	1.33	0.186	-0.15	0.76
	Knowledge	0.13	0.03	0.23	4.04	0.000**	0.07	0.20
	Interest	0.44	0.04	0.59	10.61	0.000**	0.36	0.53
2	(Constant)	6.45	0.26		24.36	0.000	5.93	6.97
	Gender	0.37	0.21	0.10	1.74	0.083	-0.05	0.79
	Major	0.28	0.23	0.07	1.19	0.235	-0.18	0.74
	Knowledge	0.13	0.03	0.24	4.08	0.000**	0.07	0.20
	Interest	0.44	0.04	0.58	10.45	0.000**	0.36	0.52
	InterestXKnowledge	-0.01	0.01	-0.05	-0.82	0.416	-0.04	0.02

*Note. **. Correlation is significant at the 0.01 level (2-tailed).*

Simple slope analysis.

When the interaction was graphed, the relationship between topic interest and attitudes towards HABs causes and effects was found to depend only slightly on students' level of topic knowledge. A stronger relationship emerged between topic interest and attitudes at lower levels than at higher levels of topic knowledge. A simple slope analysis showed that at a level of one standard deviation below the mean for the topic knowledge variable and cause and effect, *b=.474, t=11.746, p < .001*, and one standard deviation above *b=.408, t=8.382, p < .001,* accordingly Cohen (1988) states that 13% explained variance (f^2=.018) is considered small effect in multiple regression analysis. The results of the slope analysis are shown in Figure 4. The results of the analyses reported above are summarized at the end of this chapter. The results are further described with relation to theory and practice in chapter five of this study.

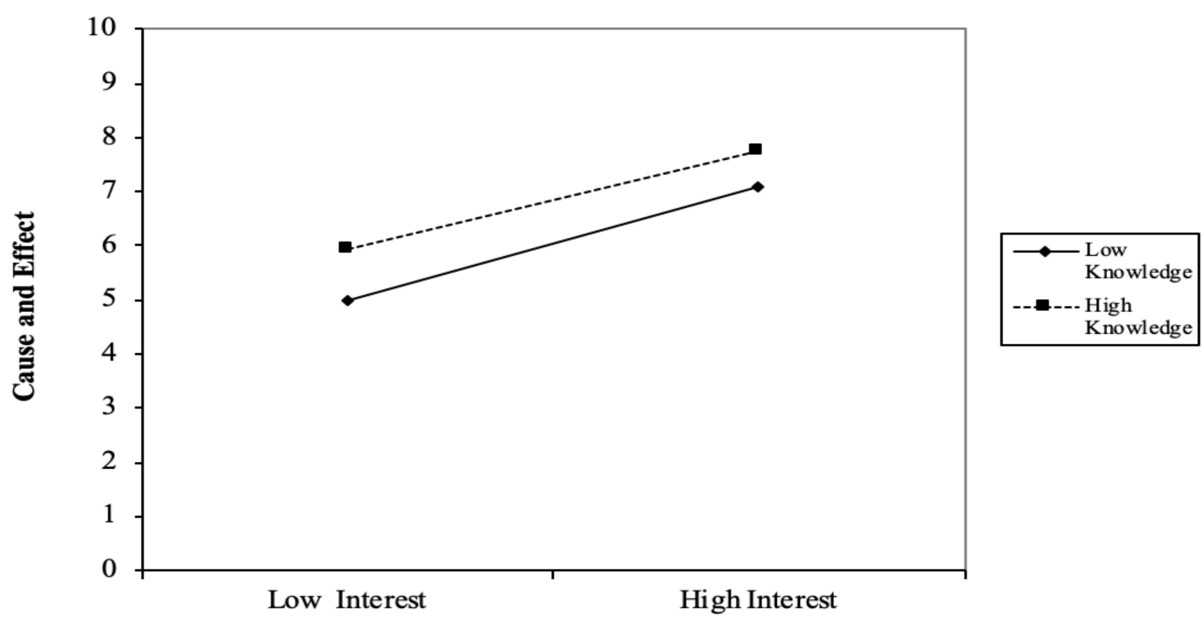

Figure 4. Interactions Between Topic Interest and Topic Knowledge for Cause and Effect Attitudes

Hierarchical Multiple Regression and Slope Analyses Summary

Topic knowledge was shown to be a better predictor of risk beliefs than topic interest, major, or gender. A negative correlation suggests that the more knowledgeable a participant was, the more they believe harmful algal blooms to be unsafe. The results from regression analysis for risk, show the interaction term (interestXknowledge) was a unique predictor and topic knowledge remained as a significant predictor of participants' risk attitudes in step two of the model. When topic interest and topic knowledge interactions were graphed, the results indicate that the relationship between topic interest and attitude towards HABs risks depended on students' level of topic knowledge with a stronger relationship observed at lower than at higher levels of topic knowledge.

Both topic interest and topic knowledge emerged as better predictors for beliefs about cause and effects over gender or major. Topic interest and topic knowledge were unique predictors based on correlation analysis for cause and effect, the results suggest that the more interested or knowledgeable participants are, the higher their causes and effects attitude levels. Of the two variables, topic interest and topic knowledge, topic interest was a stronger predictor of cause and effect beliefs with topic interest explaining more of the variation seen in cause and effect attitude scores. Regression analysis showed that while topic interest and topic knowledge independently are predictors of cause and effect attitudes, the interaction between the two was not a significant predictor of cause and effect. The interaction graph between topic interest and topic knowledge indicates that the relationship between topic interest and attitude towards HABs causes and effects depends only slightly on students' level of topic knowledge with a stronger relationship observed at higher than lower levels of topic knowledge.

Participant interviews provided details to help further describe undergraduates' topic interest, topic knowledge and attitudes towards HABs and help explain some of the variations seen in the regression analysis. The results of the interviews are discussed in the following section.

Qualitative Analysis

In one-on-one, face-to-face, semi-structured interviews, participants were asked about their knowledge and interest regarding HABs and their recommendations for HAB resource design. The responses for the six participant interviews are grouped by question and presented in Table 18. A summary of participant responses for each question is also presented below. The implications of participant responses are discussed in chapter five of this study, and a summary of the major findings from this section is presented at the end of this chapter.

Interviews with participants revealed several details about their learner characteristics related to HABs. Specifically, participants described their sources of motivation, sources of prior knowledge, and preferences for HABs resource design. Participants had a range of sources of prior knowledge, half of the participants had no prior experience and very little knowledge related HABs but all of the participants had heard of algae. A few of the participants had never heard of a HAB before the survey but had prior experiences with non-harmful algae. None of the participants could recall HABs being discussed by their professors, stating that it may have been covered in their college course but only briefly, not enough to leave an impact.

The most common factor respondents stated for participating in the survey and interviews was a belief that research is important/it is important to help research. Some participants, in addition to being motivated by the importance of research were also motivated by social contexts such as a teacher or family member placing importance on the topic. Many participants commented that passion for the environment or environmental issues in general motivated them to take an interest in HABs. A high self-efficacy based on prior knowledge and experience with the topic was mentioned by a few participants as their source of motivation for engaging with the topic. As well, the incentives offered were also a source of motivation to participate in the survey and follow-up interviews.

All of the participants commented that the topic of HABs should be made more relevant to their daily lives, but participant suggestions were split down the middle, with half recommending social media and half recommending more formal resources and settings for resource design.

Table 18. Interview Responses Grouped by Question and Participant

Participant	Interview Questions 1-3 and Responses		
	Have you heard of HABs?	**Can you explain what they are?**	**Where did you hear/ what did you learn about them?**
1	Yes, I saw it on the internet. It wasn't like BuzzFeed or anything like that. It was just a website, like national algae protection or something like that.	So harmful algae bloom is when there's a lot of algae. It releases toxins into the water, and it can, I think, clog the gills of fish and kill them. And also, I think it affects humans too.	I've learned about algae a little bit in high school but very briefly. So I knew what it was and kind of the general idea about what it does. But after I went to a lake on vacation and they were having a bloom, I looked more information up about it, and I found out other stuff.
2	No, when I was in Africa, there was this part of the beach that I went to and there was just a whole lot of blooms and I didn't think anything of it. It was really obvious, but I didn't think anything like, "This is dangerous."	I feel like if anything-- I don't know if it correlates with pollution or anything like that because I did a project on water pollution, ocean, and things of such, but I was kind of wondering how it would affect the blooms. I didn't really google anything because the survey said don't google so I didn't really look.	N/a
3	Just vague impressions in my mind. I feel like I've heard about it before, but I don't have a concrete idea of when or how.	Not really, but I can assume from the name HAB, it has something to do with algae growing out of control and causing harm.	N/a
4	No, not before the survey.	No not really, So in the email of the survey, it said not to do any research. So I didn't.	N/a
5	I first read a news article or something about it. Crimson tide or something like that. I think it was in like 2015.	Its algae that is toxic to the fish, toxic to the people. Because it's kind of scary down South. Don't go out, you'll get the infections in your lungs. It's affecting people. People are dying so I'm like, "It's a little bit scary." It's been a few years that either it'll come and go and it'll get really bad or it'll stay for a while. And then people are like, "When is this going to go away?"	I know it was a huge thing kind of in local elections of picking people who would take that [HABs policy] as a top priority. So that was kind of a concern for me. I learned about it from that and some in school.

Participant	Interview Questions 1-3 and Responses		
	Have you heard of HABs?	**Can you explain what they are?**	**Where did you hear/ what did you learn about them?**
6	So basically what I know is what I learned in high school	I learned that algae blooms, they make the water hypoxic. So fish cannot breathe and things like that. So it leaves a lot of dead bodies and when they die, decomposers also eat them so that's more algae and things like that. And then basically, they block sunlight so no more photosynthesis, things like that. And then, yeah, it's very dangerous and basically one major cause is the runoff from fertilizer.	So I took AP environmental science. And from there, I learned about harmful algae blooms.

Participant	Interview Questions 4-7 and Responses			
	Do you remember learning about HABs in college?	**How knowledgeable would you say you are on the topic?**	**How knowledgeable and interested do you think your peers are?**	**How interested in HABs are you?**
1	No	Medium	Lower	Medium to low, there are a lot more interesting things than algae, but I am into climate change and things like that.
2	I feel like we may have talked about it maybe sometime, but not in-depth as much for me to really remember.	Low	Same	Very interested, I wanted to know more about the blooms
3	No	Low	Same	Medium to low. It's interesting, but it doesn't currently affect my life. Yeah, we're pretty inland.
4	No	Low	Same	Medium to low, it's not that relevant to me.
5	No	High	Lower, it's not really a thing that people know about very widely. I think just because I'm pretty directly connected to it that I know about it and am interested, that's why others aren't.	Very interested. So for me, I think it's important because I love the ocean. I love going out. I love enjoying it. I love fishing and eating.
6	It was about algae and something about how there's certain places they grow and-- I don't really remember it that well because I don't think they taught on it so long. I remember kelp. Kelp is what I remember concerning sea urchins eating the kelp and the kelp not being able to be in certain places because of the tide and things of such. But in terms of harmful blooms, no.	High	Lower	Very interested, I am a little bit passionate about environmental issues and things like that.

Participant	Interview Questions 8-10 and Responses		
	What motivated you to participate in the interview and survey?	**What do you think would make you more interested in the topic?**	**How would you like to learn about the topic?**
1	Yeah, you could say I'm all about helping out with research. Mainly because it's an important thing.	Some big names should hop on the algae grind. People are always on social media, always looking at Instagram. I follow Leonardo DiCaprio. He's a big environmentalist. So yeah, I'd say through social media, rather than just posting on a website and hoping that people look at it. You're not going to get a lot of people who just take that extra step to just go on and voluntarily do the research.	Data is definitely more convincing. But human stories is just more interesting. So yeah, a little-- the best of both worlds on social media.
2	I always take any survey that people send me just to help them, any other surveys that were offered in class, my friend's surveys that they have. I usually take them in general.	I think something that is really striking and grabs people's attention. If you talk about the effects-- I don't know, something maybe like a poster or maybe social media. Like if a video came up on social media. Something that's eye-catching. They're like, oh my God, I'll share.	You can take a picture of a fish with a big injury on social media and say, "What do you think caused this?" And then, yeah, something like that and then you can go right into the harmful blooms.
3	Well, basically, our teacher asked us to do it. And, as for the follow-up interview, I had time and it seemed like a good cause.	Ya I would want to know what it is, and how it affects us, and any kind of news bulletins that have to do with it, how it relates to other fields of study, and environmental concerns, and how it leads back to our lives, yeah.	Just like a basic text rundown would be a good one.
4	I think being able to participate in research is important and because I know it can be hard to find participants.	Tie it to something more relevant.	Well, on social media you can kind of look at how there's been a wave of banning plastic straws, and I see how that's been a cause and effect. That's the first thing I thought. I would want to hear something about how harmful algae blooms relate to other things in the environment like that.

Participant	Interview Questions 8-10 and Responses		
	What motivated you to participate in the interview and survey?	**What do you think would make you more interested in the topic?**	**How would you like to learn about the topic?**
5	I would say just because I have some type of knowledge base and connection to it, that I probably have more to say about it than other people who are up here and really don't pay attention to it. I got interested in the subject because I do have family out in an area who have been directly affected by it [HABs] because they can't go up to the beach. But I just have my cousins who are out there and they're in high school and they want to go out and have fun at the beach. And it's important, my grandma is like, "No. People are dying."	So kind of showing the effect that it has on people, I feel like, will help open their eyes and think, "Okay, so this is an issue that happens, this isn't just a one-off thing," and kind of marking that persistence year over year.	So I think the specific case study for the people that are in my class will at least start to get that going in people's heads and might spark some type of interest to go and look further into it. Like probably on spring break. People want to get away and go down South and it [HABs] kind of messes up your plans.
6	I knew what the topic was on. I feel if the survey was something I never knew before I wouldn't sign up for the interview. Yeah. So because I knew about algae blooms and then the incentive as well. So that's why I signed up.	In a classroom setting, I guess because I feel that's the best way to reach our peers and things like that. It is a topic in school where the kids will have to get a grade if we test on it. They will definitely take interest. And then for me, it was just like I was tested on this type of subject. And I even went to-- I actually am interested in things like this. So it might reach our peers in the way that they want to start taking action but who knows.	I still say in a class is the best way. In a classroom setting, we will learn how and ways to take action against these-- the topic about algae blooms, it was just how can we prevent it, how to take actions. So to cover all those topics with one social media post or things like that, might be harder.

Summary of Participant Interview Responses by Question

Based on the data reported in Table 18, participant responses were summarized for each interview question and the results are presented below.

"Have you heard of HABs?" Three participants had heard of algae but not of HABs. One of those participants experienced an algal bloom while traveling but it was not a HAB. Three participants had heard of HABs. Participants mentioned having heard about HABs from prior experiences with websites, traveling, news sources, and in high school biology

"Can you explain what they are?" Three of the participants who had never heard of a HAB, did not offer an explanation for what they are. One of the participants who had heard of algae and had prior experiences with an algal bloom but not of a HAB, asked questions about the connection between HABs and pollution. Two of the three participants who had not heard of a HAB mentioned not doing any research or searching for answers while participating in the study. In their explanations, the three participants who had heard of HABs identified the following risks, and cause and effects they felt were associated with bloom events:

i. a. Risk of HAB toxins in the water
   b. Clogs the gills of fish and kills them
   c. Effects for humans (did not mention specific effects)

ii. a. Toxic to fish and toxic to people- mentioned lung infection and death (fish and people)
   b. Algae blooms can occur sporadically and for short time periods, can also be reoccuring or occur for long time periods

iii. a. Blooms cause hypoxia water conditions which kills fish
   b. Increased nutrients from dead fish and algae contribute to more blooms
   c. Then algae blocks sunlight for other photosynthetic organisms
   d. HABs caused by runoff from fertilizers, human activity

"Where did you hear/what did you learn about them?" The three participants who had not heard of HABs, did not have an answer for this question. The three participants who had heard of

HABs elaborated on their prior knowledge. All three mentioned learning something about HABs in high school. One participant described, after learning about it in high school, a bloom event experienced while traveling led to further research about HABs using government websites. Another participant described after studying it in high school, they noticed the topic was important in local elections through news articles. One participant specifically mentioned a source of their HABs knowledge is from the course AP Environmental Science.

"Do you remember learning about HABs in college?" Four of the participants said they do not remember learning about HABs in their college courses. Two participants said HABs may have been taught in their college courses but that it wasn't in depth and so they didn't remember. Of the two, one participant mentioned remembering that algae (kelp) struggles to grow because of pressures from invasive species but did not mention HABs.

"How knowledgeable would you say you are on the topic?" The three participants who had not heard of a HAB ranked themselves as having low knowledge on the subject. One participant who had heard of HABs ranked themself as having a medium level of knowledge and the remaining participants who had heard of HABs ranked themselves as having high knowledge levels.

"How knowledgeable and interested do you think your peers are?" The three participants who had not heard of HABs ranked their peers as having the same level of interest and knowledge as compared to themselves. The three participants who had heard of HABs ranked their peers as having lower interest and knowledge levels as compared to themselves. One participant offered a reason for peers having lower interest and knowledge levels, it isn't a widely known topic unless one is directly connected to it.

"How interested in HABs are you?" Three of the participants stated they were very interested in the topic. Out of these three participants, one of them had not heard about HABs and was interested out of curiosity. One stated their interest was related to passion for the environment (love of the ocean), and the other stated their interest was based on passion for environmental issues. Similarly, one participant that rated their interest level from medium to low mentioned issues such as climate change are interesting, but alage itself is not that interesting. That participant had heard of HABs previously. The other two participants that rated their interest levels as medium to low had not heard of HABs and commented their reason for medium to low interest levels are due to HABs not being personally relevant. One of the participants specified that HABs aren't personally relevant because they live inland.

"What motivated you to participate in the interview and survey?" Four participants commented that their motivation was related to the feeling that research is important/helping with research is important. One of those participants further commented that social context motivated them. Two participants commented that they were motivated by high self-efficacy in the topic. One of those further commented that social context was an additional motivational factor. The other stated that high self-efficacy and the study incentives motivated them to participate.

"What do you think would make you more interested in the topic?" Participants' recommendations for encouraging interest in the topic are as follows:

b. Use of big names to promote discussion on the topic via social media
c. Use of videos and posters, shareworthy content on social media
d. Make the topic more personally relevant (stated explicitly by two participants)
e. Show the effects HABs have on people and that HABs can be occur yearly
f. Use a classroom setting, students will be engaged because they will be grade

“How would you like to learn about the topic?” Participants stated they would like to learn about HABs in the following ways:

g. Use of data and human stories on social media
h. Use of pictures and stories of cause and effects on social media
i. Use of social media to make connection to bigger environmental issues like banning plastic straws
j. Use of text
k. Use of case study based on a relevant example like spring break being interrupted because of a HAB.
l. Use a classroom setting that teaches ways to take action

The findings reported in this section are further summarized in the next section and the implications are discussed in chapter five.

Chapter Summary

Based on the sample population’s mean scores, their topic interest levels were moderate, they held moderate to high beliefs in the cause and effects of HABs, low risk attitude levels (meaning HABs are seen as a risk and unsafe), and had low topic knowledge levels in general. Several misconceptions were identified related to students’ risk attitudes and topic knowledge, and less related to their cause and effect beliefs. The results of the ANOVA, correlation and regression analyses, and participant interviews are summarized in the next paragraphs.

Gender and major did not statistically significantly interact together to influence risk, cause and effect, topic interest, or topic knowledge scores. Gender did not have an effect on risk, cause and effect, topic interest, or topic knowledge; there was no significant difference in mean scores between males and females. Gender did not have a significant effect on mean scores between science and non-science majors. Major had a statistically significant effect on mean topic interest and topic knowledge scores. Science majors had higher topic interest and topic knowledge scores, however major did not have an effect on risk or cause and effect mean scores. Major emerged as a better predictor of topic interest and topic knowledge than gender. To answer the first research question, “Are there differences between science and non-science majors topic interest, topic knowledge, and attitudes towards HABs?,” there is a slight difference between science majors and non-science majors topic interest and topic knowledge mean scores, however there was no difference observed in their attitude scores.

Correlation analysis revealed a moderately statistically significant negative correlation between risk and topic knowledge, with topic knowledge explaining 19% of the variation in risk. A strong statistically significant positive correlation between cause and effect and topic interest, with topic interest explaining 33% of the variation in cause and effect. In addition, a moderate statistically significant positive correlation between cause and effect and topic knowledge, with topic knowledge explaining 5% of the variation in cause and effect, was found. Major had a small statistically significant negative correlation with topic interest, major explaining 2% of the variation in topic interest. Major had a moderate statistically significant negative correlation with topic knowledge, with major explaining 10% of the variation in knowledge. A positive correlation between HABs interest and HABs knowledge, was found but the strength of the association is weak.

Topic knowledge was shown to be a better predictor of risk beliefs than topic interest, major, or gender. A negative correlation suggests that the more knowledgeable a participant was, the more they believe harmful algal blooms to be unsafe. The results from regression analysis for risk, show the interaction term (interestXknowledge) was a unique predictor and topic knowledge remained as a significant predictor of participants’ risk attitudes in step two of the model. When topic interest and topic knowledge interactions were graphed, the results indicate that the relationship between topic interest and attitude towards HABs risks depended on students' level of topic knowledge with a stronger relationship observed at lower than at higher levels of topic knowledge.

Both topic interest and topic knowledge emerged as better predictors for beliefs about cause and effects over gender or major. Topic interest and topic knowledge were unique predictors based on correlation analysis for cause and effect; the results suggest that the more interested or knowledgeable participants are, the higher their causes and effects attitude levels. Of the two variables, topic interest and topic knowledge, topic interest was a stronger predictor of cause and effect beliefs with topic interest explaining more of the variation seen in cause and effect attitude scores. Regression analysis showed that while topic interest and topic knowledge independently are predictors of cause and effect attitudes, the interaction between the two was not a significant predictor of cause and effect. The interaction graph between topic interest and topic knowledge indicates that the relationship between topic interest and attitude towards HABs causes and effects depends only slightly on students' level of topic knowledge with a stronger relationship observed at higher than lower levels of topic knowledge.

To answer the second research question, “do topic interest and topic knowledge independently and interactively predict attitudes towards HABs?,” topic knowledge and the interaction between topic knowledge and topic interest emerged as the best predictors of risk attitudes. Topic interest emerged as the best predictor of cause and effect attitudes.

To answer the third research question, “What do interviews with survey respondents reveal about participant learner characteristics and their recommendations for HABs education and outreach resource design?," follow-up interviews with survey participants were summarized based on the interview questions. When participants were asked about their prior experiences and knowledge related to HABs, all had heard of algae but half of the participants had not heard of or encountered a HAB. Participants who had heard of HABs reported learning about the topic from news or websites, high school biology, living in an area prone to HABs, or experiencing a bloom event while traveling. None of the participants could recall HABs being discussed by their professors, stating that it may have been covered but only briefly and not enough to leave an impact.

In the follow-up interviews, participants described several different sources of motivation for engaging in the topic, however, none of the participants explicitly stated an interest in HABs as their source of motivation. Participants' sources of motivation included, a belief that research is important/it is important to help research, general interest in environmental issues, the influence of social contexts, high self-efficacy, and incentives.

All participants commented that low interest and knowledge levels in HABs are most likely because of the belief that HABs are not personally relevant. Participants were asked for their recommendations for future HABs education and outreach resource design\ and their responses were evenly split. Half of the participants suggested the use of "share worthy" social media and other media resources. "Share worthy" included the use of celebrities or data combined with human stories, showing the attention-grabbing aspects of HABs impacts, and media resources included posters, pictures and videos. The half that reported they do not use social media cited recommendations such as the use of text, case studies and classroom instruction that teaches students how to take action on the topic. Similar to when asked about their sources of motivation, the participants thought that whatever the medium of communication, it should be made more relevant to their everyday lives.

The themes that emerged in relation to participants' sources of motivation, prior knowledge, and recommendations for resource design are discussed in light of the results from the quantitative analyses with regard to implications for practice in Chapter V of this study.

CHAPTER V: DISCUSSION

This mixed-methods study utilized a QUANTITATIVE and qualitative approach. It had several purposes; (a) to explore possible differences between science majors' and non-science majors' topic interest, topic knowledge, and attitudes towards HABs, (b) to investigate the potential context-specificity of the mechanisms, topic interest, and topic knowledge, and the relationships between them that may influence attitudes towards HABs, (c) to gain insight into participants' learner characteristics, prior knowledge and interest, and preferences for resource design, and (d) utilize the study results to discuss implications for future HABs education and outreach efforts. This chapter included a discussion of the major findings related to the research questions for this study and the literature on prior HABs education and outreach, HABs research, and the CRKM learner characteristics prior knowledge and motivation. This chapter also discussed the implications of the study findings with relation to practice, the limitations of the study, suggestions for future research, and concluded with a brief summary.

This chapter focused on a discussion of the findings and future research to help answer the study research questions:

Quantitative:

1. Are there differences between science majors and non-science majors' topic interest, topic knowledge and attitude levels regarding HABs?
2. Do undergraduate students' topic interest in and their topic knowledge about harmful algal blooms predict their attitudes towards HABs?
    a. Do undergraduate students' interest in and their knowledge about harmful algal blooms, independently and interactively, predict their attitudes towards the risks associated with HABs?
    b. Do undergraduate students' interest in and their knowledge about harmful algal blooms, independently and interactively, predict their attitudes towards the causes and effects of HABs?

Qualitative:

3. What do interviews with survey respondents reveal about participant learner characteristics and their recommendations for HABs education and outreach resource design?

Across the board, participant topic interest and topic knowledge scores indicate that they had generally low interest in HABs and low conceptual and factual knowledge related to HABs. Science majors had slightly higher interest and knowledge levels than did non-science majors, but given the low participation of science majors in the study overall, this should be viewed in context. Major did not have an effect on attitudes towards HABs. Topic knowledge was a better predictor of risk attitudes. The relationship between interest and risk depended on students' level of topic knowledge and a stronger relationship was observed at lower levels than at higher levels of topic knowledge. Only participants' topic interest and topic knowledge significantly interacted to predict risk attitudes. Both topic interest and topic knowledge were predictors of cause and effect attitudes, however, topic interest was a stronger predictor. The relationship between topic interest and attitudes towards HABs causes and effects depended only slightly on students' level of topic knowledge, a stronger relationship emerged between topic interest and attitudes at lower levels than at higher levels of topic knowledge. Participants reported their sources of motivation were related to a belief that research is important, interest in other environmental issues, social context, self-efficacy, and incentives. Participants who had heard of HABs reported learning about the topic from news or websites, high school biology, living in an area prone to HABs, or experiencing a bloom event while traveling. All of these factors provide details regarding ways to better engage undergraduates in the topic and improve HAB education and outreach efforts.

Differences Between Groups

As was expected, gender was not found to have an effect on participant mean scores for any of the variables. Although there were statistically significant differences between science and non-science majors' topic interest and topic knowledge scores, with science majors scoring higher on both measures, neither group was that different from the participant mean scores as a whole group. This was not expected and suggested that with regard to HABs, participant characteristics were more like the general public, i.e. no differences seen between groups, as opposed to the expected differences seen between majors and other science topics. Meaning that science major scores are not described differently than non-science major scores. Participant mean survey scores in general revealed that they had a medium level of topic interest and a low level of topic knowledge. There were no statistically significant differences between science and non-science major risk, and cause and effect attitude scores. These findings are consistent with those of Kirkpatrick et al (2014) that found the level of HABs knowledge did not vary based on age, gender, or education level but that knowledge levels in general were low. All interview participants commented that low interest and knowledge levels results are most likely because of the belief that HABs are not personally relevant. This study did not observe findings similar to Cotner, et al. (2017) that suggested non-science majors were more likely to find science topics as less personally relevant. These findings suggest that there are other factors that influence participant scores that have more of an effect than gender or major.

Relationships Between Variables and Predictors of Attitudes

The findings from the regression analyses implied that the more knowledgeable participants were the more likely they were to be concerned about the potential risk of HABs than were less knowledgeable participants, and more interested participants were more likely to believe the causes and effects of HABs to be true than were less interested participants. These results are in line with the literature explaining the roles of motivation and cognition involved in attitude formation (Dole & Sinatra, 1998; Petty & Briñol, 2012). Additionally, the results are consistent with relevant models on the roles of interest and knowledge in learning and understanding science (Alexander, 1997; Guthrie & Wigfield, 2000).

Risk.

As was expected, topic knowledge was a better predictor of risk attitudes. Though the predictability of topic interest and topic knowledge were demonstrated in first-order terms for both risk and cause and effect attitudes, only participants' topic interest and topic knowledge significantly interacted to predict risk attitudes. The relationship between interest and risk depended on students' level of topic knowledge and a stronger relationship was observed at lower levels than at higher levels of topic knowledge. This result is consistent with research by Stenseth et al (2016) that looked at the relationship between topic interest, topic knowledge, and attitudes towards the risk of nuclear power. A possible explanation is that having higher topic knowledge can decrease the influence motivation has in attitude formation if an issue is considered to be uninteresting, unimportant, or lack personal relevance (Pettey and Wegener, 1999). Therefore, participants who had low topic knowledge but high topic interest may be using their interest over their knowledge to inform their beliefs about the risks of HABs.

Cause and effect.

Both topic interest and topic knowledge were predictors of cause and effect attitudes, however, as was expected, topic interest was a stronger predictor. The relationship between topic interest and attitudes towards HABs causes and effects was unexpectedly found to depend only slightly on students' level of topic knowledge, a stronger relationship emerged between topic interest and attitudes at lower levels than at higher levels of topic knowledge. This finding is similar to and different from Stenseth et al (2016). Their results similarly showed that topic interest was a stronger predictor of the belief in human causation of climate change than topic knowledge but in their study, the interaction between topic interest and topic knowledge was also a significant predictor with a stronger relationship at higher than at lower levels of topic knowledge. These results could be explained by considering that the influence of interest on attitudes becomes stronger as knowledge levels increase (Gauchat, 2012) and in situations where an individual lacks topic knowledge, they may be more likely to rely on their interest to form an opinion, even if the opinion is inconsistent with scientific knowledge and consensus (Murphy, 2001). Participants that had higher levels of personal involvement and were previously engaged with the topic are more likely to attach values and beliefs towards the topic (Hidi, 2001). However, as in the explanation of risk attitudes described above, if the issue is not considered personally relevant or interesting, high topic knowledge can decrease the influence motivation has in attitude formation (Pettey and Wegener, 1999). Therefore, depending on a participants level of topic knowledge, they may be using their topic interest over their topic knowledge to influence their beliefs about the causes and effects of HABs.

Sources of Prior Knowledge and Motivation

The qualitative analysis offers more details to help understand CRKM learner characteristics, prior knowledge, and motivation. Participant interviews provided insights into why topic knowledge levels might be low; all had heard of algae but half of the participants had not heard of or encountered a HAB. Participants who had heard of HABs reported learning about the topic from news or websites, high school biology, living in an area prone to HABs, or experiencing a bloom event while traveling. Participants were unable to recall any instances where HABs were discussed in their undergraduate courses. These findings suggest that participants likely lack opportunities to engage at a high level with HABs content and may also be limited in the conceptual and factual details that foster attitudes that are supported by evidence-based explanations (Dole and Sinatra, 1998). Additionally, the participants' reported sources of prior knowledge reflected the research by Hardy et al (2016) that show HABs are communicated through a variety of ways and that the coherence of the intended messages is lacking; there are no guidelines for effective communication strategies.

Sources of participant motivation to engage in the topic indicated that the actual interest level of participants explicitly related to HABs is likely lower than the observed findings. None of the participants mentioned an interest in HABs as a motivating factor. Instead, they stated their sources of motivation to engage in the topic were related to: (a) a belief that research is important/it is important to help with research; (b) a general interest in bigger environmental issues like climate change; (c) the influence of social contexts like professors and family members; (d) a high self-efficacy due to high topic knowledge and prior experience, or; (e) incentives like extra credit and gift cards. Participants' reported sources of motivation are consistent with the alternative sources of motivation proposed in the CRKM (Dole and Sinatra, 1998). The implications of the findings from this study with relation to science education practices are discussed below.

Implications for Practice

Undergraduates in this study had several misconceptions associated with their topic knowledge; 10 out of the 14 questions on the knowledge survey measure had an incorrect response rate of greater than 40%. This is consistent with prior HABs research conducted by Nierenberg et al (2010) that used a survey to look at tourist versus residents' knowledge of Florida red tide and a survey conducted by Smith et al. (2014) to understand what fishermen know about freshwater HABs in Louisiana. Both studies found widely inconsistent and incorrect responses across participating groups, likely signifying a substantial lack of knowledge and prevalence of misconceptions in the public's knowledge of HABs (Nierenberg et al., 2010; Smith et al., 2014).

The results of this study indicated that participants had several misconceptions related to their beliefs about the risk towards HABs. For example, participants accurately believed harvesting and fishing during HABs to be a risk, but they inaccurately believed buying fish and shellfish from a restaurant or supermarket is just as much of a risk. Participants who had high topic knowledge in general thought HABs were a high level of risk the more interested in the topic they were. Whereas participants who had low knowledge found HABs to be safe and not really a risk at all the more interested they were in the topic. This finding suggested that participants may lack the topic knowledge or conceptual coherence in order to accurately inform their decisions about the risks of HABs, another possible explanation is that HABs messages are inconsistent and participants do not know that there are precautions in place to keep seafood in supermarkets and restaurants safe for consumption. Existing conceptions are more susceptible to change when conceptual coherence is lacking (Thagard, 1992). Conceptual change is less likely to occur the stronger the existing idea is (Eagly & Chaiken, 1993), suggesting that the participants who have misconceptions about their beliefs and also have high topic knowledge may be less likely to change their beliefs about HABs. In order to address misconceptions related to risk attitudes, it is important for educators to identify and address where conceptual knowledge lacks coherence. Presenting HABs as being more personally relevant to participants and connecting HABs to other environmental issues such as climate change, could increase their interest to engage in the topic which would encourage knowledge revision to occur in participants who have misconceptions and also have a high level of HABs topic knowledge (Dole & Sinatra, 1998; Pettey and Wegener, 1999).

Participants, in general, had strong attitudes about the risk associated with HABs, believing HABs to pose a significant risk. Depending on the commitment level of their belief, an individual who holds strongly to the belief that HABs are a risk or that they are not a risk may not change their misconceptions regardless of the strength and coherence of their prior knowledge (Dole & Sinatra, 1998). Beliefs that are more moderately held are more susceptible to change, so individuals who have strongly held beliefs that HABs are not a risk or ones that believe HABs to be overly risky may require considerable effort to change existing beliefs. Undergraduates should engage in focused instruction, with opportunities for new schema to be formed around appropriate and accurate risk perceptions related to HABs. Education and outreach efforts should focus on the methods in place to alert the public of HAB risks and that agencies test for and monitor HAB toxins in food. Resources should also address the lack of prior knowledge or coherence likely related to participants not fully grasping content specific topics like food web relationships or connections between toxin and concentration levels for toxicity.

The results of this study indicated that participants had few misconceptions related to their beliefs about the causes and effects regarding HABs and that their interest more than their knowledge influenced their beliefs. The misconception that stands out the most is that participants did not believe HABs to have effects on their everyday lives. This result was consistent with what participant interview responses revealed and is also seen in participants' low topic interest levels. Interest should be leveraged to engage participants to confront their misconceptions towards cause and effects of HABs. Participants should be provided with ample opportunity to build their topic knowledge to help them form an attitude that is in line with and supported by their interest levels and scientific knowledge (Kahan et al., 2012). Education and outreach efforts need to highlight how HABs is a local, regional, and global issue that can have many different kinds of effects of varying degrees, depending on where they live, or on an individual's daily life. Examples should be used that illustrate that HABs can occur inland in places like Kansas (Trevino-Garrison et al., 2015) just as easily as they can near a seashore or lake area in order to challenge participants' existing conceptions.

Similar to when asked about their sources of motivation, the participants thought that whatever the medium of engagement, it should be made more relevant to their everyday lives. This is in line with the suggestion by Kober (2015) that science topics can be made more engaging by connecting issues to an individual's everyday life. Participants were asked for their recommendations for future HABs education and outreach resource design; their responses were evenly split. Half of the participants suggested the use of "share worthy" social media and other media resources. “Share worthy” included the use of celebrities or data combined with human stories, showing the attention grabbing aspects of HABs impacts; media resources included posters, pictures, and videos. The half that reported they do not use social media cited recommendations such as the use of text, case studies, and classroom instruction that teaches students how to take action on the topic. This finding is consistent with the arguments made by Pechenkina and Aeschliman (2017) that how higher education students engage with social media in a learning context is varied and related to the value they attach to social media in general and within a specific learning context. Given participant recommendations and the literature about social media’s use in instruction, social media could be used to alert about and informally communicate HABs. Hardy et al (2016) used social media to send HAB alerts to lake residences in Washington state, they found that the alerts did serve to decrease recreational lake use during bloom events but that the perception of how useful social media is, was undetermined. Social media could also be used as an initial hook to grab participant attention, although arguably, formal instruction has the potential to make more of an impact on changing participant misconceptions and engaging them at a high cognitive level (Dole & Sinatra, 1998).

Instructional Strategies

Participants suggested that social media be used to present HABs content using data because it is more convincing and human stories because they are more compelling. Education and outreach efforts can apply this as a strategy for content design that is implemented using evidence-based instructional strategies that facilitate conceptual change. Given participant suggestions to use text, case studies and classroom instruction that teaches students how to take action about important topics. Some examples of instructional resources that meet their recommendations and are successful in addressing misconceptions include refutational texts, socio-biological case-based learning, and socio-scientific issue framework.

Refutational tests.

Refutational texts are structured to include elements of argumentation that directly confront an individual's misconception by using causal explanations based on scientific evidence to counter incorrect knowledge (Kendeou, Walsh, Smith, & O'Brien, 2014). Additionally, refutational texts have been cited as a more effective conceptual change intervention than expository texts (Heddy & Sinatra, 2013; Heddy et al., 2017; Tippett, 2010). An example case that could be the topic for refutational text is discussed in Chapter II and is the case of the 2015 bloom of *Pseudo-nitzschia* species, *P. australis*, that produced the highest concentrations of domoic acid ever recorded in Monterey Bay, CA. Warm temperatures were cited as the culprit for triggering the bloom event, however researchers showed that to be an inaccurate explanation for the causes of that bloom (Ryan et al., 2017). Using refutational text could challenge the misconception that HABs are always caused by warming temperatures. HABs education and outreach efforts should also include refutational texts that focus on addressing incorrect topic knowledge related to things like inaccurate risk attitudes and address misconceptions that HABs only occur in specific places like near the coast.

Socio-biological case-based learning.

Socio-biological case-based learning is described as, "a model of problem-based learning by placing biological cases as a problem to be explained and solved through a series of investigative activities," (Suwono, Pratiwi, Susanto, & Susilo, 2017, p. 213). Compared to using lecture-based learning, socio-biological case-based learning showed a significant increase in biological literacy and critical thinking skills in participants (Suwono et al., 2017). HABs education and outreach resources can be designed to connect with existing learning topics used in socio-biological case-based learning and taken from general biology courses to better address gaps in topic knowledge. For example, one topic focuses on biodiversity, growth, and development of plants. Participants can be introduced to algae and HABs by first understanding plants. Then, they could engage in investigations that look at the features that make algae different and similar to plants, why algae are not considered plants, how plants and algae can grow out of control, and what we can learn from invasive plants that relate to controlling and mitigating HABs. Another example would be to highlight the role of algae as a primary producer in different food webs and investigate HAB toxin levels in different organisms before and after bloom events and then focus on how this has effects on our food supply.

An article by Pelley (2016) in *Chemical & Engineering News* that discussed the debate scientists are having over the best way to tame toxic algal blooms could be a useful refutational text that is then built on through socio-biological case-based learning. Scientists agree that phosphorus inputs should be cut, however, some scientists are now suggesting that nitrogen should also be controlled in order to mitigate HAB events. Students would have to make several biological connections, among them nutrient cycling in the environment such as the phosphorous paradigm, and then decide which argument is best supported. Moreover, students would have to consider the social impacts related to drinking water contamination. Pelley (2016) provides a quote by an environmental engineer, Daniel Obenour, that can be used to ask students to form a position and present evidence to support their thinking, “We know we can manage nitrogen,” Obenour says, “but we haven’t decided if the costs are worth the improvement in water quality,” (p. 23).

Socio-scientific issues.

HABs has the potential to be viewed as a socio-scientific issue (SSI) and used in SSI instruction. SSI is a conceptual framework used to guide practice in science education with the goal of fostering scientific literacy (Zeidler, 2015). SSI unifies multiple epistemological orientations and perspectives, as well as considers an individual's emotions and character development as critical to effective science education (Zeidler, 2015). SSI should contain the following elements (Zeidler, 2015 p. 998): (a) controversial and ill-structured problems that require scientific evidence-based reasoning to inform decisions about the topic, (b) deliberate use of a scientific topic with social ramifications that require students to engage in dialogue, discussion, debate, and argumentation, (c) an issue that has implicit and explicit ethical components and requires some degree of moral reasoning, and (d) often includes the formation of virtue/ character as a long-range pedagogical goal.

An example of HABs discussed as an SSI could be focusing on the link between human activity and HABs, like why and how the habits of farmers can significantly increase the likelihood and severity of bloom events. How HAB events are triggered by human activity is often linked to the habits of farmers; they may not know, understand, or be able to easily change their habits and this could create conflict between farmers, the general public, and policy makers. The research by Smith et al (2018) points out that despite farmers’ efforts to reduce the use of fertilizer according to current guidelines, the media and the public continue to blame them as the reason for re-eutrophication in Lake Erie. Their research however showed that most farmers are either below thresholds or are following the guidelines, and that instead a multitude of factors are contributing to re-eutrophication in Lake Erie,

> Wholesale agronomic changes (e.g., no-tillage adoption, crop cultivar advances, and fertilizer application and formulation) have occurred since current fertilizer recommendations were developed. Although crop P uptake mechanisms have not changed, these agronomic changes have altered P cycling in soil and water (p. 48).

They suggested that current guidelines need to be seriously considered as contributing to eutrophication over the habits of farmers.

To aid students in their study of the Lake Erie re-eutrophication debate, a multi-criteria decision analysis tool that was developed by Pang et al (2017) could be used. Their proposed framework was applied to harmful algal bloom management in order to demonstrate that it can be used to analyze multiple perspectives and the priorities of a variety of stakeholders with relation to considerations for HABs mitigation efforts, human health, environmental impact, social impact, and technical feasibility.

By utilizing an SSI framework for HABs education and outreach resources, students could learn about the how and why mechanisms of HABs and then could deliberate the best way to respect farmers while addressing the issue of nutrient runoff that can cause a HAB event. Students could then focus on their own actions that may contribute to HAB events. In this way, SSI also speaks to the advice given by Bauer (2006) that educators can aid in addressing the challenges in HABs education and outreach efforts by "focusing communications to promote public behaviors that reduce vulnerability and respond to impacts of HABs," (p. 33).

Based on participant suggestions, the goals of HABs education and outreach, and the results of this study, the use of refutational texts, socio-biological case-based learning and socio-scientific issue (SSI) instruction are recommended to more effectively communicate HABs because of the potential each strategy has to: (a) specifically address misconceptions; (b) facilitate conceptual change; (c) increase cognitive engagement; (d) show connections to everyday life; (e) promote opportunities for students to interact with HABs content at high levels of cognitive engagement; and (f) aid in making HABs messages more coherent, plausible, comprehensive, and compelling to undergraduates.

Limitations and Recommendations for Future Research

This study was conducted at a private research university in the north eastern United States with a small sample size. The results may not be generalizable to other populations, groups of undergraduates, or other cultures and countries. Future research should continue to examine the differences in interest, knowledge, and attitudes regarding HABs that may exist between groups of students and in other contexts to assess the generalizability of this study's findings. Due to lack of sample size, location was not considered in the analyses but this could be a strong predictor of interest, knowledge, and attitudes towards HABs that was not investigated. Future studies should focus on location as a variable.

A small sample size also affected the number of interview responses. This is a significant limitation to the robustness of the qualitative analysis for this study because interview responses were not systematically coded based on the literature but instead were summarized based on each interview question. In order for a more robust qualitative analysis of undergraduate learner characteristics related to HABs a larger sample size is necessary. Future research should continue to explore effective recruitment strategies that increase not only survey participation but also elicit more participant input through interviews. Qualitative data collection strategies could also be expanded to include focus group interviews, in addition to one-to-one interviews and an online discussion board or chat room to reach the most participants.

There are aspects of motivation and prior knowledge as well as other affective, cognitive, and behavioral factors that provide input for attitude formation and misconceptions that were not explored in this study, warranting continued research on alternate variables that may be more influential than the ones in this study. For example, the results of this study indicate that a general interest in environmental issues may be a bigger motivator than an actual interest in HABs; future studies should examine this potential influence further. A single cross-sectional mixed methods study cannot fully unravel the contribution of one variable to another. The results of this study indicated that there are relationships between interest, knowledge, and attitudes towards HABs using ANOVA and regression analyses. However, given the results of this study, structural equation modeling could be used to provide greater detail and depth regarding the value of interest and knowledge as predictors of attitudes towards HABs. Structural equation modeling could then be used to develop a model of the relationships and factors that influence attitudes towards HABs.

A limitation of this study's methodology is that it can not determine causality. It was assumed, based on prior research, that there is a relationship between interest, knowledge, and attitudes with interest and knowledge having the potential to act as causal predictors of attitudes. That assumption was further explored in this study. Although the observed findings from this study are consistent with the assumption, longitudinal, and experimental studies should be done to be able to make more concrete causal statements about the relationships between interest, knowledge, and attitudes regarding HABs.

Likewise, this study inferred the message characteristics related to HABs (plausibility, compressibility, coherence, and rhetorically compelling) based on participants' level of topic knowledge and prior HABs studies and literature and did not explicitly examine this aspect of the CRKM as the focus of this study was to explore learner characteristics. However, given the findings of this study, participants had low-interest levels and the interactions between interest and knowledge on their attitudes. Future research should be done to understand how much message characteristics contribute. A CRKM features that was not considered in this study are peripheral cues. Future research should include the role peripheral cues could play in addressing misconceptions towards HABs via the CRKM. In making the topic more relevant to undergraduates, future resources could be evaluated in terms of their message characteristics with relation to learner characteristics. A recently developed tool by Heddy, Taasoobshirazi, Chancey, and Danielson (2018) could be used to quantitatively assess the level of conceptual change cognitive engagement with relation to a particular intervention.

The data are self reported, science major was not operationalized for participants, so they made their selections based on their view of science major which is unknown. Addiotionally, the self-reported data may be influenced by many factors that are beyond the control of this study's methodology. Respondents were asked not to research their answers but there is no data about how many of them looked up or guessed their responses. Future surveys should consider adding questions about the level of confidence participants have in their responses as well as the amount they guessed to form a response. A time limit was not given for the survey because participants might be using mobile phones or have varying wifi quality, in a more controlled setting, a time limit could be useful in determining a more accurate picture of participants' topic knowledge.

During participant interviews however, several participants commented that the directions asked them to not research their responses and they abided by the request. The use of incentives, as well as an already high interest in the topic, is likely to have drawn a specific type of person to respond, so there is a group of participants that is not represented in this study that is likely to have low interest in the topic. Although efforts were made to contact survey and interview non-responders, data about why they didn't participate and what their thoughts are is not available. In order to create relevant resources, their voices are necessary and future research should include efforts to learn their perspectives.

Language may have been a limitation of this study as well. English language is not the first language for many undergraduates. This group of students may have had trouble in understanding the survey but still participated in the survey for other reasons and may have skewed the data. This data was not collected and so it isn't known how many survey participants this applied to and how it may have affected the results of this study. Future research should focus on making survey materials accessible in different languages or include questions that ask about comfortability with the survey language used. At least one interview participant expressed being nervous about doing the survey and interview because of their lack of knowledge on the subject. Finding ways to address this issue and make people more comfortable participating should be part of future methodology.

Resource design recommendations were only asked of interview participants to try and reduce survey fatigue, though given the valuable insights provided by interview participants' recommendations, future use of HABs surveys should include the ability for participants to leave open ended responses and give their input. Given that the results for resource recommendations were split, some recommending more traditional resource designs and some recommending social media, future research should further explore how best to leverage both types of resources and understand what types of students prefer social media over traditional methods and why.

Conclusions

HABs are a growing concern in the US and abroad. Persistent misconceptions regarding HABs increases the negative effects of bloom events by decreasing the effectiveness of communication efforts and impeding mitigation, monitoring, and recovery efforts. Improving education and outreach strategies is a necessary step in achieving the goal of functional HABs literacy. Science education courses provide an appropriate atmosphere to engage undergraduates in HABs. Understanding undergraduate students' topic interest, topic knowledge, and attitudes towards HABs is critical to addressing their misconceptions through relevant and engaging means. There is little related research to aid educators in tackling the challenge. This study approached the challenges involved in effectively communicating HABs by examining understudied groups and variables to make implications for education and outreach resource design. This study contributed to the literature by continuing to investigate the characteristics between science and non-science majors, providing evidence for the anteceding effects of topic interest and topic knowledge on attitudes towards HABs, highlighting participant sources of motivation and prior knowledge, and eliciting participant input for effective communication strategies regarding HABs.

Findings from this study suggested that science majors had slightly higher interest and knowledge levels than did non-science majors. Major did not have an effect on attitudes towards HABs. The results further indicated that participants had several misconceptions related to their beliefs about the risk towards HABs. Education and outreach efforts should focus on letting undergraduates know about the methods in place to alert the public of HAB risks and that agencies test for and monitor HAB toxins in food. Participants who had high topic knowledge in general thought HABs were a high level of risk the more interested in the topic they were. Whereas participants who had low knowledge found HABs to be safe and not really a risk at all the more interested they were in the topic. These findings suggested that participants may lack the topic knowledge or conceptual coherence in order to accurately inform their decisions about the risks of HABs. Another possible explanation is that HABs messages are inconsistent and participants do not know that there are precautions in place to keep seafood in supermarkets and restaurants safe for consumption.

Participants had few misconceptions related to their beliefs about the causes and effects regarding HABs and that their interest more than their knowledge influenced their beliefs. This result was consistent with what participant interview responses revealed and is also seen in participants' low topic interest levels. Presenting HABs as being more personally relevant to participants and connecting HABs to other environmental issues such as climate change, could increase their interest to engage in the topic which would encourage knowledge revision to occur in participants who have misconceptions and also have a high level of HABs topic knowledge. Education and outreach efforts need to highlight how HABs is a local, regional, and global issue that can have many different kinds of effects of varying degrees, depending on where they live, on an individual's daily life.

Participant interviews provided insights into why topic interest and topic knowledge levels might be low, none of the participants mentioned an interest in HABs as a motivating factor to engage with the topic, half of the participants had not heard of a HAB, and many of the participants did not have prior opportunities to engage with HABs in high school or undergraduate coursework. Participants who had heard of HABs reported learning about the topic from: (a) news or websites; (b) high school biology; (c) living in an area prone to HABs or; (d) experiencing a bloom event while traveling. The participants reported that they did not find this topic to be personally relevant to their daily lives. Participants reported their sources of motivation were instead related to: (a) a belief that research is important; (b) interest in other environmental issues; (c) social context; (d) self-efficacy, and; (e) incentives. They suggested that to best engage undergraduates in HABs the following strategies should be used, (a) social media; (b) human stories and data; (c) text; (d) case studies, and; (e) classroom instruction that teaches students how to take action on the topic. Given participant suggestions, some examples of instructional resources that meet their recommendations and are useful in facilitating conceptual change include, refutational texts, socio-biological case-based learning, and socio-scientific issue framework.

HABs need to be framed in a way in which students can clearly see that it is a topic that is personally relevant to them, and educators need to specially address misconceptions that may contribute to inaccurate beliefs about the risks of HABs. The results of this study suggested that topic interest and topic knowledge can act as predictors of attitudes towards HABs. These findings provided a baseline for future research to build on and details to help educators investigate HABs with their students. Given the negative consequences related to bloom events, the fact that there is no one solution to HABs issues, and no known solution to keeping HABs from occurring, seeking to foster functional HABs literacy, is the most viable solution for managing HABs issues now and in the future.

Appendix A: Syracuse University IRB Approval

SYRACUSE UNIVERSITY

INSTITUTIONAL REVIEW BOARD
MEMORANDUM

TO: John Tillotson
DATE: September 20, 2019
SUBJECT: **Amendment for Exempt Protocol**
AMENDMENT#: 3 – A) Consent Form Changes (Revised);
B) Change in and/or Addition of Research Instruments/Tools
C) Change in Recruitment Materials/Methods (New)
IRB #: 19-108
TITLE: *Understanding Perceptions About Harmful Algal Blooms*

Your current exempt protocol has been re-evaluated by the Institutional Review Board (IRB) with the inclusion of the above referenced amendment. Based on the information you have provided, this amendment is authorized and continues to be assigned to category **2**. This protocol remains in effect from **April 19, 2019** to **April 18, 2024**.

CHANGES TO PROTOCOL: Proposed changes to this protocol during the period for which IRB authorization has already been given, cannot be initiated without additional IRB review. If there is a change in your research, you should notify the IRB immediately to determine whether your research protocol continues to qualify for exemption or if submission of an expedited or full board IRB protocol is required. Information about the University's human participants protection program can be found at: http://researchintegrity.syr.edu/human-research/. Protocol changes are requested on an amendment application available on the IRB web site; please reference your IRB number and attach any documents that are being amended.

STUDY COMPLETION: The completion of a study must be reported to the IRB within 14 days.

Thank you for your cooperation in our shared efforts to assure that the rights and welfare of people participating in research are protected.

Tracy J. Cromp

Tracy Cromp, M.S.W.
Director

DEPT: Science Teaching, Heroy Geology Building – Rm. 112 **STUDENT:** Alia Thompson

Research Integrity and Protections | 214 Lyman Hall | Syracuse, NY 13244-1200 | 315.443.3013 | **orip.syr.edu**

Appendix B: Informed Consent

Teaching and Leadership
SYRACUSE UNIVERSITY

Understanding perceptions about harmful algal blooms.

My name is Alia Thompson, and I am a graduate student under professor Dr. John Tillotson who is in the Department of Science Teaching in the College of Arts and Sciences at Syracuse University. I am in the Department of Teaching and Leadership in the School of Education.

I am interested in learning about your knowledge of, interest in and attitudes towards harmful algal blooms. Maybe you have heard of harmful algal blooms, maybe you have not, I am looking for any participant over the age of 18. The aim of this study is to gain insight into your understanding of harmful algal blooms in order to better communicate science issues.

To participate in the study, you will be asked to take an online survey through Qualtrics. The survey will take approximately 10-15 minutes of your time. In the survey, you will be asked to rate your interest in harmful algal blooms, answer factual and conceptual questions about harmful algal blooms and rate your attitudes towards harmful algal blooms. Demographic information will also be asked, like age, gender, major, and geographic region you lived most of your life in. The purpose of asking those questions is to be able to discuss the results of this study in relation to previous studies. You will be asked your email address for use in an amazon gift card drawing and recruitment for subsequent interview participants based on survey data. The survey does not seek to identify specific individuals, email addresses will not be used for analysis or reporting of results.

I am inviting you to participate in my research study, "Understanding perceptions towards harmful algal blooms." Involvement in the study is voluntary. This means you can choose whether to participate and that you may withdraw from the survey at any time without penalty. Your participation in the survey will not affect your grade or standing in the course. The risk of participation is minimal, no more than a typical internet survey and the inconvenience associated with the time spent completing the survey.

The benefits of participating in the study are contributing to baseline information to potentially help researchers and policy makers better communicate science issues. You may also benefit from increased awareness about harmful algal blooms and your approaches to learning science issues. The results of this study will be included in my dissertation research and may also be used for publication in scientific journals, conferences and workshops. An additional benefit to participating in the survey is that once completing the survey you will be entered for an amazon gift card drawing of $50. You must however complete the survey in its entirety to be eligible, persons who do not complete the survey, or whose survey responses do not reflect full participation (i.e. just clicked through the survey) will not be eligible. Again you can opt out at any time from the survey BUT you must list your email and not skip questions to be eligible for the

drawing. Your survey responses are not tied to your drawing entry. Once the drawing is complete, your email information will be deleted.

Whenever one works with email or the internet; there is always the risk of compromising privacy, confidentiality, and/or anonymity. Your confidentiality will be maintained to the degree permitted by the technology being used. It is important for you to understand that no guarantees can be made regarding the interception of data sent via the internet by third parties. The data will be kept in a shared drive only Dr. Tillotson and I have access to. When using the data, all possible efforts will be made to strip it of individual identifiers.

If you have any questions, concerns or complaints about the research please contact, Alia Thompson at anthomps@syr.edu, 315-443-2586 or Dr. John Tillotson at jwtillot@syr.edu, 315-443-9137. If you have any questions about your rights as a research participant, you have questions, concerns, or complaints that you wish to address to someone other than the investigator, if you cannot reach the investigator, please contact the Syracuse University Institutional Review Board at 315-443-3013.

I am 18 years of age or older and I understand what my participation in this research involves. I have printed a copy of this form for my personal records.

By continuing, I agree to participate in this research study.

Appendix C: Pilot Study Instrument

I. Attitudes

Please rate your feelings with relation to the following statements about harmful algal blooms. Rate agreement with statements on a 10-point scale ranging from 1 (not at all true of me) to 10 (very true of me).

a) I believe that harmful algal blooms can be caused by human activities
b) I believe that runoff from fertilizers can lead to harmful algal blooms
c) I believe that people themselves are responsible for harmful algal blooms
d) I believe that harmful algal blooms are an issue for the tourist industry
e) I believe research and monitoring for harmful algal blooms are important political issues
f) I believe that harmful algal blooms can have effects on human health
g) I believe that harmful algal blooms can have effects on the marine mammals
h) I believe that harmful algal blooms can affect my daily life
i) I believe harmful algal blooms are a global problem
j) I believe harmful algal blooms are an important economic issue
k) I believe harmful algal blooms are only an issue for people who live near the coast
l) I believe that harmful algal blooms are a risk to drinking water contamination
m) I believe it is safe to travel to a beach during a harmful algal bloom
n) I believe it is safe to swim during a harmful algal bloom
o) I believe it is safe to harvest shellfish during a harmful algal bloom
p) I believe it is safe to catch and eat fish during a harmful algal bloom
q) I believe it is safe to eat shellfish from a store/ restaurant during a harmful algal bloom
r) I believe it is safe to eat fish from a store / restaurant during a harmful algal bloom
s) I believe skin, eye and respiratory irritations are risks of harmful algal blooms

II. Interest

In the following statements we want to know to what extent you are interested and engaged in harmful algal bloom issues. Rate your interest on a 10-point scale ranging from 1 (NOT AT ALL true of me) to 10 (VERY true of me).

a) I'm interested in harmful algal bloom policy
b) I'm interested in issues concerning harmful algal blooms
c) I think that more people should become actively involved in efforts to develop monitoring and communication resources for harmful algal blooms
d) I participate in discussions on harmful algal blooms
e) I am interested in what conditions influence harmful algal blooms
f) I can imagine being a member of an organization that works with natural and environmental issues
g) Health effects of harmful algal blooms is a topic that interests me
h) I am concerned with how I myself can contribute to the reduction of harmful algal blooms
i) I try to convince others that harmful algal blooms may have risks for human health
j) I am interested in issues concerning water pollution

k) I support organizations that work to reduce water pollution
l) I like to keep myself updated on issues concerning harmful algal blooms
m) I am interested in the effects of algal blooms on society
n) In the media more emphasis should be given to social or political issues related to harmful algal blooms

III. Knowledge

Below are some questions about central topics concerning harmful algal bloom issues. Please select the statement that you believe is most accurate.

1. An algal bloom is composed of
   - **a. colonies of algae or bacteria that grow out of control.**
   - b. residues from human waste that build up.
   - c. colonies of algae that grow out of control.
   - d. colonies of microscopic animals that grow out of control.
   - e. colonies of microscopic plants that grow out of control.

2. Algal blooms occur in
   - a. marine environments only.
   - b. freshwater environments only.
   - **c. both marine and freshwater environments.**
   - d. only in water that does not flow.
   - e. only in areas where freshwater and seawater meet.

3. A harmful algal bloom is
   - a. rapid and uncontrolled growth of algae that ALWAYS secrete toxins.
   - b. **rapid and uncontrolled growth of algae that can sometimes secrete toxins.**
   - c. rapid and uncontrolled growth of algae that DOES NOT secrete toxins.
   - d. rapid and uncontrolled growth of any kind of algae.
   - e. None of the above

4. Plastics
   - a. play no role in a harmful algal bloom.
   - b. can emit toxins that are absorbed by harmful algal blooms.
   - c. are the main cause of harmful algal blooms.
   - d. can be good to help stop harmful algal blooms from spreading.
   - **e. can absorb toxins produced by harmful algal blooms.**

5. Algal blooms occur
   - a. rarely, once every few years.
   - b. on the same days every year.
   - c. more than once a year, not related to the seasons.

d. whenever conditions are favorable.
e. in the summertime when the weather is warm.

6. Harmful algal blooms are caused by
   a. pollution.
   b. fertilizer.
   c. weather.
   d. a combination of factors that are the same for all types of blooms.
   e. a combination of factors that depend on the type of bloom.

7. Algal blooms
   a. are increasing in frequency and duration.
   b. are increasing in frequency and decreasing in duration.
   c. are staying the same.
   d. are increasing in duration and decreasing in frequency.
   e. are decreasing in frequency and duration.

8. Phytoplankton
   a. are single or multicellular photosynthetic organisms.
   b. are microscopic animals in the ocean.
   c. is the process of using light energy to bind carbons to form sugars.
   d. is an environment made of different types of organisms.
   e. are not related to algal blooms.

9. Algal blooms
   a. can only be red and are known as a Red Tide.
   b. always have a color.
   c. are only red and green.
   d. have no color.
   e. can have a variety of colors or none at all.

10. Harmful algal blooms
    a. can increase because of human activity.
    b. are not affected by human activity.
    c. the effects of human impact on harmful algal blooms are not known.
    d. are caused by human activity.
    e. are caused by climate change.

11. Algae
    a. are not useful in the environment.
    b. are food for many organisms.
    c. are always microscopic.
    d. growth can be easily predicted.
    e. are all very similar.

12. Algae blooms
    a. always produce a harmful toxin.

b. sometimes produce a toxin but it is not harmful to humans.
c. never produce a harmful toxin.
d. sometimes produce a toxin that becomes harmful when it reaches a certain concentration.
e. sometimes produce a toxin that is harmful no matter the concentration.

13. An algal bloom
    a. in freshwater could affect a marine environment because of animals transporting toxic algae.
    b. in freshwater could affect a marine environment by being washed downstream.
    c. can only occur in marine environments
    d. would only have an effect on other environments that are close by.
    e. in one area would have no effect on any other, freshwater or marine environments.

14. Possible negative effects of harmful algal blooms include a
    a. decrease in dissolved oxygen and increase in carbon dioxide in the water.
    b. increase in dissolved oxygen in the water and decrease in carbon dioxide in the water.
    c. increase in dissolved oxygen in the water.
    d. increase in both dissolved carbon dioxide and oxygen in the water.
    e. decrease in both dissolved carbon dioxide and oxygen in the water.

IV. Please answer a few demographic questions about yourself.

1) What is your intended or declared major?
    a) Non-science major:
    b) Science major:
    c) ESF major:
2) Gender
    a) Female
    b) Male
    c) Another gender identity (Please specify):
    d) Prefer not to answer
3) Where have you lived most of your life?
    a) Region 1: Northeast
        i) Division 1: New England (Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont)
        ii) Division 2: Mid-Atlantic (New Jersey, New York, and Pennsylvania)
    b) Region 2: Midwest
        i) Division 3: East North Central (Illinois, Indiana, Michigan, Ohio, and Wisconsin)
        ii) Division 4: West North Central (Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, and South Dakota)

c) Region 3: South
    i) Division 5: South Atlantic (Delaware, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, District of Columbia, and West Virginia)
    ii) Division 6: East South Central (Alabama, Kentucky, Mississippi, and Tennessee)
    iii) Division 7: West South Central (Arkansas, Louisiana, Oklahoma, and Texas)
d) Region 4: West
    i) Division 8: Mountain (Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, and Wyoming)
    ii) Division 9: Pacific (Alaska, California, Hawaii, Oregon, and Washington)
e) US territories and Puerto Rico
f) International

Appendix D: Study Survey Instrument

I. Attitudes

Please rate your feelings with relation to the following statements about harmful algal blooms. Rate agreement with statements on a 10-point scale ranging from 1 (not at all true of me) to 10 (very true of me).

Cause and Effect (Heading not included in survey)

**** Denotes main changes made to survey***

1. I believe that harmful algal blooms are caused by human activities.
2. I believe that runoff from fertilizers can lead to harmful algal blooms.
3. I believe that people are not solely responsible for causing harmful algal blooms.
4. I believe harmful algal blooms can have effects on the tourism industry.
5. I believe politics can have effects on the research and monitoring of harmful algal blooms.
6. I believe that harmful algal blooms can have effects on human health.
7. I believe that harmful algal blooms can have effects on marine mammals.
8. I believe that harmful algal blooms can have effects on my daily life.
9. I believe the effects of harmful algal blooms can be seen globally.
10. I believe harmful algal blooms can have economic effects.
11. ***I believe that harmful algal blooms can cause drinking water contamination**.
12. ***I believe skin, eye and respiratory irritations can be effects of harmful algal blooms**.

Risk (Heading not included in survey)

1. ***I believe the effects of harmful algal blooms are only a risk for people who live near the coast.**
2. I believe it is safe to travel to a beach during a harmful algal bloom.
3. I believe it is safe to swim during a harmful algal bloom.
4. I believe it is safe to harvest shellfish during a harmful algal bloom.
5. I believe it is safe to catch and eat fish during a harmful algal bloom.
6. I believe it is safe to eat shellfish from a store/ restaurant during a harmful algal bloom.
7. I believe it is safe to eat fish from a store / restaurant during a harmful algal bloom.

II. Interest

In the following statements we want to know to what extent you are interested and engaged in harmful algal bloom issues. Rate your interest on a 10-point scale ranging from 1 (NOT AT ALL true of me) to 10 (VERY true of me).

1. I'm interested in harmful algal bloom policy
2. I'm interested in issues concerning harmful algal blooms
3. I think that more people should become actively involved in efforts to develop monitoring and communication resources for harmful algal blooms
4. I participate in discussions about harmful algal blooms
5. I am interested in what conditions influence harmful algal blooms

6. I can imagine being a member of an organization that works with natural and environmental issues
7. The health effects of harmful algal blooms is a topic that interests me
8. I am concerned with how I myself can contribute to the reduction of harmful algal blooms
9. I try to convince others that harmful algal blooms may have risks for human health
10. I am interested in issues concerning water pollution
11. I support organizations that work to reduce water pollution
12. I like to keep myself updated on issues concerning harmful algal blooms
13. I am interested in the effects of algal blooms on society
14. In the media more emphasis should be given to social or political issues related to harmful algal blooms

III. Knowledge

Below are some questions about central topics concerning harmful algal bloom issues. Please select the statement that you believe is most accurate.

1. An algal bloom is composed of
    - **a. colonies of algae or bacteria that grow out of control.**
    - b. residues from human waste that build up.
    - c. colonies of algae that grow out of control.
    - d. colonies of microscopic animals that grow out of control.
    - e. colonies of microscopic plants that grow out of control.

2. Algal blooms occur in
    - a. marine environments only.
    - b. freshwater environments only.
    - **c. both marine and freshwater environments.**
    - d. only in water that does not flow.
    - e. only in areas where freshwater and seawater meet.

3. A harmful algal bloom is
    - a. rapid and uncontrolled growth of algae that ALWAYS secrete toxins.
    - **b. rapid and uncontrolled growth of algae that can sometimes secrete toxins.**
    - c. rapid and uncontrolled growth of algae that DOES NOT secrete toxins.
    - d. rapid and uncontrolled growth of any kind of algae.
    - e. None of the above

4. Plastics
    - a. play no role in a harmful algal bloom.
    - b. can emit toxins that are absorbed by harmful algal blooms.
    - c. are the main cause of harmful algal blooms.
    - d. can be good to help stop harmful algal blooms from spreading.

e. can absorb toxins produced by harmful algal blooms.

5. Algal blooms occur
   a. rarely, once every few years.
   b. on the same days every year.
   c. more than once a year, not related to the seasons.
   d. whenever conditions are favorable.
   e. in the summertime when the weather is warm.

6. Harmful algal blooms are caused by
   a. pollution.
   b. fertilizer.
   c. weather.
   d. a combination of factors that are the same for all types of blooms.
   e. a combination of factors that depend on the type of bloom.

7. Algal blooms
   a. are increasing in frequency and duration.
   b. are increasing in frequency and decreasing in duration.
   c. are staying the same.
   d. are increasing in duration and decreasing in frequency.
   e. are decreasing in frequency and duration.

8. Phytoplankton
   a. are single or multicellular photosynthetic organisms.
   b. are microscopic animals in the ocean.
   c. is the process of using light energy to bind carbons to form sugars.
   d. is an environment made of different types of organisms.
   e. are not related to algal blooms.

9. Algal blooms
   a. can only be red and are known as a Red Tide.
   b. always have a color.
   c. are only red and green.
   d. have no color.
   e. can have a variety of colors or none at all.

10. Harmful algal blooms
    a. can increase because of human activity.
    b. are not affected by human activity.
    c. the effects of human impact on harmful algal blooms are not known.
    d. are caused by human activity.
    e. are caused by climate change.

11. Algae
    a. are not useful in the environment.
    b. are food for many organisms.

c. are always microscopic.
d. growth can be easily predicted.
e. are all very similar.

12. Algae blooms
    a. always produce a harmful toxin.
    b. sometimes produce a toxin but it is not harmful to humans.
    c. never produce a harmful toxin.
    d. sometimes produce a toxin that becomes harmful when it reaches a certain concentration.
    e. sometimes produce a toxin that is harmful no matter the concentration.

13. An algal bloom
    a. in freshwater could affect a marine environment because of animals transporting toxic algae.
    b. **in freshwater could affect a marine environment by being washed downstream**.
    c. can only occur in marine environments
    d. would only have an effect on other environments that are close by.
    e. in one area would have no effect on any other, freshwater or marine environments.

14. Possible negative effects of harmful algal blooms include a
    a. decrease in dissolved oxygen and increase in carbon dioxide in the water.
    b. increase in dissolved oxygen in the water and decrease in carbon dioxide in the water.
    c. increase in dissolved oxygen in the water.
    d. increase in both dissolved carbon dioxide and oxygen in the water.
    e. decrease in both dissolved carbon dioxide and oxygen in the water.

IV. Please answer a few demographic questions about yourself.

1. What is your intended or declared major?
    1. Non-science major:
    2. Science major:
2. Gender
    1. Female
    2. Male
    3. Another gender identity (Please specify):
    4. Prefer not to answer
3. Email address:
4. Where have you lived most of your life?
    1. New England (Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont)
    2. Mid-Atlantic (New Jersey, New York, and Pennsylvania)

3. East North Central (Illinois, Indiana, Michigan, Ohio, and Wisconsin)
4. West North Central (Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, and South Dakota)
5. South Atlantic (Delaware, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, District of Columbia, and West Virginia)
6. East South Central (Alabama, Kentucky, Mississippi, and Tennessee)
7. West South Central (Arkansas, Louisiana, Oklahoma, and Texas)
8. Mountain (Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, and Wyoming)
9. Pacific (Alaska, California, Hawaii, Oregon, and Washington)
10. US territories and Puerto Rico
11. International

Appendix E: Knowledge Survey Items- Percent of Response by Question Options
***Bolded Option Indicates Desired Response**

Q1 - An algal bloom is composed of:

Options	% of Response
colonies of microscopic plants that grow out of control.	12.61%
residues from human waste that build up.	11.71%
colonies of algae or bacteria that grow out of control.	**50.90%**
colonies of microscopic animals that grow out of control.	3.60%
colonies of algae that grow out of control.	21.17%

Q2 - Algal blooms occur in:

Options	% of Response
only in water that does not flow.	10.36%
marine environments only.	8.56%
freshwater environments only.	4.50%
both marine and freshwater environments.	**72.97%**
only in areas where freshwater and seawater meet.	3.60%

Q3 - A harmful algal bloom is:

Options	% of Response
rapid and uncontrolled growth of algae that ALWAYS secrete toxins.	27.93%
rapid and uncontrolled growth of any kind of algae.	21.17%
rapid and uncontrolled growth of algae that can sometimes secrete toxins.	**43.69%**
rapid and uncontrolled growth of algae that DOES NOT secrete toxins.	4.50%
None of the above	2.70%

Q4 - Plastics:

Options	% of Response
play no role in a harmful algal bloom.	8.11%
can emit toxins that are absorbed by harmful algal blooms.	61.71%
are the main cause of harmful algal blooms.	18.92%
can be good to help stop harmful algal blooms from spreading.	7.21%
can absorb toxins produced by harmful algal blooms.	**4.05%**

Q5 - Algal blooms occur:

Options	% of Response
rarely, once every few years.	6.76%
on the same days every year.	5.41%
whenever conditions are favorable.	**63.06%**
more than once a year, not related to the seasons.	17.12%
in the summertime when the weather is warm.	7.66%

Q6 - Harmful algal blooms are caused by:

Options	% of Response
pollution.	18.43%
fertilizer.	12.44%
weather.	4.15%
a combination of factors that depend on the type of bloom.	**56.68%**
a combination of factors that are the same for all types of blooms.	8.29%

Q7 - Algal blooms:

Options	% of Response
are increasing in frequency and decreasing in duration.	16.59%
are increasing in duration and decreasing in frequency.	18.89%
are staying the same.	5.99%
are increasing in frequency and duration.	**56.68%**
are decreasing in frequency and duration.	1.84%

Q8 - Phytoplankton:

Options	% of Response
are microscopic animals in the ocean.	37.33%
is the process of using light energy to bind carbons to form sugars.	11.06%
is an environment made of different types of organisms.	11.98%
are single or multicellular photosynthetic organisms.	**37.33%**
are not related to algal blooms.	2.30%

Q9 - Algal blooms:

Options	% of Response
can only be red and are known as a Red Tide.	9.68%
always have a color.	11.98%
are only red and green.	15.67%
have no color.	5.99%
can have a variety of colors or none at all.	**56.68%**

Q10 - Harmful algal blooms:

Options	% of Response
can increase because of human activity.	**58.53%**
are not affected by human activity.	5.07%
the effects of human impact on harmful algal blooms are not known.	15.21%
are caused by human activity.	14.75%
are caused by climate change.	6.45%

Q11 - Algae:

Options	% of Response
are not useful in the environment.	7.08%
are always microscopic.	11.32%
growth can be easily predicted.	16.51%
are all very similar.	8.49%
are food for many organisms.	**56.60%**

Q12 - Algae blooms:

Options	% of Response
always produce a harmful toxin.	13.21%
sometimes produce a toxin but it is not harmful to humans.	15.57%
never produce a harmful toxin.	6.60%
sometimes produce a toxin that is harmful no matter the concentration.	23.11%
sometimes produce a toxin that becomes harmful when it reaches a certain concentration.	**41.51%**

Q13 - An algal bloom:

Options	% of Response
in freshwater could affect a marine environment because of animals transporting toxic algae.	37.74%
would only have an effect on other environments that are close by.	17.45%
can only occur where there is pollution.	12.74%
in freshwater could affect a marine environment by being washed downstream.	**25.94%**
in one area would have no effect on any other, freshwater or marine environments.	6.13%

Q14 - Possible negative effects of harmful algal blooms include a:

Options	% of Response
decrease in both dissolved carbon dioxide and oxygen in the water.	16.98%
increase in both dissolved carbon dioxide and oxygen in the water.	20.75%
increase in dissolved oxygen in the water.	11.32%
increase in dissolved oxygen in the water and decrease in carbon dioxide in the water.	16.98%
decrease in dissolved oxygen and increase in carbon dioxide in the water.	**33.96%**

Appendix F: Interview Guide

1. Have you heard of HABs?
2. Can you explain what they are?
3. Where did you hear about them/ what did you learn about them?
4. What are your sources of HABs knowledge?
5. How knowledgeable would you say you are on the topic?
6. How knowledgeable and interested do you think your peers are?
7. How interested in HABs are you?
8. What motivated you to participate in the interview and survey?
9. What do you think would make you more interested in the topic?
10. How would you like to learn about the topic?

Appendix G: Pilot Survey Participants by Gender and Major

Gender	Major	N
Male	Science	6
	Non-science	9
	Total	15
Female	Science	13
	Non-science	37
	Total	50
Total	Science	19
	Non-science	46
	Total	65

Appendix H: Pilot Descriptive Statistics for Study Variables, *N*=65

	Mean		Std. Deviation	Varianc e	Skewness		Kurtosis	
Variable		Std. Error				Std. Error		Std. Error
Interest	4.50	0.25	2.16	4.68	0.31	0.27	-0.27	0.55
Cause_Effect	6.37	0.17	1.61	2.84	-0.119	0.25	0.29	0.50
Risk	5.60	0.05	.50	2.61	.512	0.26	.98	0.52
Knowledge	3.62	0.35	3.71	13.7	.698	0.23	-0.60	0.45

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VITA

Alia Thompson

Syracuse University, Department of Science Teaching
Heroy Geology Lab 103A
Syracuse, NY 13244-1070
anthomps@syrDOTedu

EDUCATION:

Ph.D. Science Education, School of Education, Syracuse University, Syracuse, NY, May 2020

Future Professoriate Program Certificate in University Teaching, Graduate School, Syracuse University, Syracuse, NY, April 2019

Certificate of Advanced Study in Instructional Design Foundations, Instructional Design, Development and Evaluation, Syracuse University, Syracuse, NY, December 2018

Master of Education in Curriculum Studies Hawaiian Science, College of Education, University of Hawaii at Manoa, Honolulu, HI, December 2013

Post-Baccalaureate Certificate in Teaching Secondary Science Education, College of Education, University of Hawaii at Manoa, Honolulu, HI, May 2011

Bachelor of Arts in Botany Hawaiian Ethnobotany, Department of Botany, University of Hawaii at Manoa, Honolulu, HI, December 2008

PROFESSIONAL LICENSE(S):

Teaching License, 6-12th grade Secondary Science
Hawaii Teacher Standards Board, Honolulu, HI, August 2011-June 2021 please click to view

TEACHING EXPERIENCES:

Teacher Educator for SCE 413/613 Methods and Curriculum in Teaching Science AND SCE 416/616 Assessment and Data Driven Instruction in Science
Syracuse University, Syracuse, NY, August 2016- May 2020

- Develop course material and instructional activities
- Mentor pre-service teachers
- Conduct instruction and assessments
- Assist through the NY state teacher certification process
- Please visit my teaching portfolio for more information

Summer School Science Teacher, grades 2-8, St. John Vianney Parish School, Kailua, HI
May- July 2018

- Develop course material and instructional activities
- Work collaboratively with Art, P.E. and Math teachers to create and teach interdisciplinary units
- Work with Technology teacher to integrate science concepts into summative assessments

for coding and other tech projects

7th grade Life Science Teacher, Kaimuki Middle School, Honolulu, HI
August 2011-May 2016

- Life Science teacher focusing on place-based learning and integration of Hawaiian and Western Science within an inquiry framework
- Rated as a highly effective teacher based on the Danielson framework (2013-2016) and administrator observations (DOE started using this framework in 2013).
- Rated 90% favorable responses from students taking the Tripod Survey in Spring 2014
- Rated 82% favorable responses from students taking the Tripod Survey in Fall 2015
- Mentor teacher for three pre-service teachers

INTERNSHIP(S):
Instructional Design, Development, and Evaluation Summer Internship
Stewardship Asia, Singapore, June-August 2019

- Design business training program
- Review production videos and make appropriate suggestions for edits
- Research and design case studies

Monterey Bay Aquarium Research Institute Summer Internship
Monterey Bay Aquarium Research Institute (MBARI), Monterey, CA, June-August 2017

- Design and develop online and digital educational outreach resources about harmful algal blooms
- Communicate outreach efforts to a wider audience through web resources
- Research and update existing resources

EDUCATION RESEARCH EXPERIENCE:
Research Assistant, Department of Science Teaching,
Syracuse University, NY, 2018-2020

- Working under Dr. John Tillotson, *Syracuse University STEM Talent Acceleration Initiative (SUSTAIN) Project,* National Science Foundation (NSF) Grant (NSF S-STEM Grant #1644148)

EDUCATIONAL LEADERSHIP:
Hui Ho`oulu Team Leader, Kaimuki Middle School, Honolulu, HI, July 2015-May 2016

- Coordinate team day activities and interdisciplinary units
- Facilitate weekly meetings and communication between team members
- Help to implement data teams protocols
- Attend school leadership meetings and assist core teachers in meeting school wide initiatives and goals

Hawaii State Science Teacher Association President, HaSTA, Honolulu, HI, January 2015-April 2016

- Coordinate community partnerships and opportunities for members
- Plan annual conference, for 200+ attended:
    - *"Storytelling in Science"* September 2015
      Punahou School, Honolulu, HI

- Liaison with board and association members to implement aims and policies which further HaSTA's philosophy and mission objectives
- Maintain and form new sponsorships

Science Department Head, Kaimuki Middle School, Honolulu, HI, August 2013-May 2015
- Coordinate common course and bridge activities between department faculty and across grade levels
- Liaison with administrators to implement aims and policies which further school philosophy and mission
- Coordinate professional development workshop opportunities in cooperation with community/ academic agencies/ individuals

SELECTED PUBLICATION(S)

Ceyhan, G., **Thompson, A**., Sloane, J., Tillotson, J. W., & Wiles, J. (2019). Exploring how the Strategic Undergraduate STEM Talent Acceleration INitiative (SUSTAIN) influenced students' understanding of the nature of science. *Re-introducing science Sculpting the image of science*, 523.

Ceyhan, G. D., **Thompson, A. N**., Sloane, J. D., Wiles, J. R., & Tillotson, J. W. (2019). The Socialization and Retention of Low-Income College Students: The Impact of a Wrap-Around Intervention. *International Journal of Higher Education*, *8*(6), 249-261.

Hart, P. J., Sebastián-González, E., Tanimoto, A., **Thompson, A.**, Speetjens, T., Hopkins, M., & Atencio-Picado, M. (2018). Birdsong characteristics are related to fragment size in a neotropical forest. *Animal Behaviour*, *137*, 45-52. https://www.sciencedirect.com/science/article/pii/S0003347218300101

AWARDS and DISTINCTIONS:

2019	**IDDE Study abroad, Singapore,** Syracuse University
2018	**FPP certificate in undergraduate teaching,** Syracuse University
2018	**EPI Teacher Fellowship to Baja, Mexico**, Ecology Projects International
2017	**Hilman Brown study abroad scholarship to Havana, Cuba**, Syracuse University
2015-2016	**Hawaii State Science Teachers Association (HaSTA) President,** Honolulu, HI
2014	**Clarence T.C. Ching Foundation professional development award,** DOE, Honolulu, HI
2013	**College of Education Curriculum Studies "Giving Tree" award,** University of Hawaii, Manoa
2012	**"Ka Liko Lehua" (new science teacher of the year) award,**

Hawaii Science Teacher Association

2011 **Gueco scholarship for science educators,**
Foundations University of Hawaii, Manoa

RELEVANT SKILLS:

Computer Skills: Proficient in Microsoft Office, Google Apps, common web 2.0 and 3.0 tools, basic data viz, basic coding, video editing and production, SPSS, SQL Lite, Qualtrics and NVIVO.

Languages: Fluent in English and Hawaiian Pidgin, basic knowledge of Spanish, some knowledge of Japanese and Hawaiian.

REFERENCES:

- Dr. John Tillotson, Associate Professor, Syracuse University jwtillot@syr.edu
- John Stawarz, Online Learning Librarian, Syracuse University jdstawar@syr.edu
- Dr. Gaye Ceyhan, Faculty, Boğaziçi University, Turkey, gdceyhan@syr.edu
- Doreen Elliott, Faculty, Institute for Teacher Education, UH Manoa, doreenleielliott@gmail.com