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Fight The Bite: Implementation of Mosquito-Based Curriculum in Elementary, Middle, and High Schools in Florida

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Abstract

Mosquitoes are both a nuisance and public health threat. In recent decades, outbreaks of dengue, chikungunya, and Zika in Florida have raised awareness of the importance of domestic and peri-domestic container mosquitoes, Aedes aegypti and Aedes albopictus. The synanthropic nature of these species, coupled with their preference for human bloodmeals, makes them a concern of and target for mosquito control. However, mosquito control programs (MCPs) often struggle to sustainably manage these mosquitoes because of the cryptic and abundant nature of their larval habitats, and negative public opinion towards MCPs and the use of insecticides. Fortunately, mosquito control can be improved by the actions of homeowners and residents as they have regular access to their own property and containers. School-based education programs can provide a means to community-wide education regarding mosquito control. We developed and delivered a mosquito education program to elementary, middle, and high school students. Knowledge of mosquitoes significantly improved in participating elementary and middle/ high school students. This knowledge was partially retained according to a follow-up test that was administered. Additionally, attitudes towards mosquito control and at-home control methods significantly improved following the instruction. The improvements in knowledge and attitudes observed in students suggest they can and should be targeted for mosquito education campaigns by mosquito control programs and educators.

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Introduction

Mosquitoes are one of the deadliest organisms in the world (Bosch et al., 2019; Kittayapong et al., 2017). They transmit disease-causing pathogens that result in hundreds of millions of infections globally and millions of deaths each year (World Health Organization, n.d.). Different mosquito species are vectors for different arboviruses, and each species is accompanied by its own set of challenges when it comes to control. In recent decades, outbreaks of dengue, chikungunya, and Zika in Florida have highlighted the importance of their mosquito vectors, *Aedes aegypti* and *Aedes albopictus*, that develop in small containers near human habitation, and are often referred to simply as container mosquitoes. Multiple characteristics make container mosquitoes a major concern for public health personnel and vector control: the adults are usually host-seeking during the day when humans are most active (Chadee & Martínez, 2000; Smith et al., 2018); their affinity to take bloodmeals from humans (Hawley, 1988; McBride et al., 2014; Takken & Verhulst, 2013); and the natural and artificial container habitats the larvae occupy are often closely associated with human habitation and can be cryptic and abundant (Garcia-Sánchez et al., 2017; Simard et al., 2005; Unlu et al., 2014). This makes finding and eliminating the containers regularly impractical for public health organizations.

Mosquito control agencies rely on an integrated vector management (IVM) approach that incorporates surveillance, outreach/ extension, and control through habitat alteration, biological control, and chemical control using larvicides and adulticides. Adulticide sprays can be ineffective against container mosquitoes due to asynchrony between the typical time of treatments (evenings) and the peak crepuscular activity times of container mosquitoes (Smith et al., 2018). Insecticide resistance can greatly decrease the operational efficacy of the application. In Florida, pyrethroid resistance is widespread (Estep et al., 2018; Liu et al., 2004; Parker, Ramirez, et al., 2020) and this can ultimately result in field failures of an adulticide spray, even if the adulticide reaches the adult mosquito. This presents a major obstacle for vector control to overcome to achieve mosquito population reduction. Therefore, the outreach/ extension aspect of IVM becomes arguably the most critical when it comes to controlling container mosquitoes.

Conceptual Framework

A review of literature was conducted to examine the importance and potential impact of school-based instruction to help foster effective mosquito management. The impracticality of eliminating larval habitat by local, county, and state public health agencies stems from the following: larval habitats are cryptic and abundant (Codeço et al., 2015; Unlu et al., 2014); identifying all potential larval development sites, and treating or eliminating them is not operationally feasible or sustainable; larval habitats are often located on private properties, i.e., residences and are therefore inaccessible; the resources required to undertake this extensive of a container elimination campaign far exceed the resources available, in terms of time and personnel required. However, this work need not be left only to professionals; communities can individually support control efforts through engagement in container elimination around their own homes.

Enlisting the help of individuals and volunteer organizations to help train the community on source reduction practices can significantly aid in reducing larval indices (Healy et al., 2014). The engagement of homeowners and residents can serve as a major tool in overcoming the challenges outlined above. However, in order to aid in container elimination strategies, they must first be equipped with the information necessary engage in protective practices around their home and in their community. Eliminating the larval habitats can lead to a decrease in mosquito abundance and, ultimately, increase the amount of time community members can spend outdoors (Darbro et al., 2017). Several studies have addressed the potential of the community to aid in container mosquito reduction with promising results (Ballenger-Browning & Elder, 2009; Espinoza-Gómez et al., 2002; Fonseca et al., 2013; Healy et al., 2014; Sanchez et al., 2005). A significant proportion of mosquito-education based programs have focused on adult human populations. However, the studies that have been conducted with school-aged children demonstrate that mosquito-based education can lead to improved understanding of mosquito biology and control by children, which can ultimately lead to behavior change (Lennon, 2004; Madeira et al., 2002; Yasuoka et al., 2006).

Adoption of behaviors at an early age often leads to continued implementation of those behaviors later in life (Rogers, 2010). When it comes to source reduction, educating and engaging an entire home is preferable to only engaging the adults. Children are an extra set of eyes and hands who can contribute their knowledge and enthusiasm to container elimination. Most children are present in a learning environment for a large portion of the year through the school system, which provides an ideal opportunity to educate students on mosquito biology and control.

There are also barriers to effective communication of mosquito control information to the community. Public attitudes and perceptions of mosquito control practices can play a major role in the implementation of control strategies. Recent examples of this occurred in both Miami (Karimi & Visser, 2016) and Puerto Rico (Beaubien, 2016) during the 2016 Zika outbreaks. In both areas, protests indicated fears by the residents of the products being applied aerially and mistrust of government and public health officials. In Puerto Rico, aerial spraying was ultimately blocked after public outcry and a decision by the governor to block the application. Another study in the U.S. Virgin Islands revealed aerial application was the least desired application method by homeowners when compared to hand (backpack) or truck applications (Seger et al., 2019). Misinformation can have tangible consequences that ultimately impact public health. Targeted education that addresses this misinformation has the ability to influence community receptiveness to effective mosquito control practices (Carey et al., 2020; Sommariva et al., 2018) and the knowledge needed to do their part in the control process. Therefore, equipping the public, including children, with fact-based information on mosquito control tools and protective practices is an underutilized and effective resource for improving public health outcomes. Considering the historical and present-day importance of mosquitoes and the pathogens they transmit, curriculum such as this should be an important component of the science classroom.

Purpose and Objectives

The purpose of this study was to evaluate the impact of a mosquito-based curriculum (Parker, McLeod-Morin et al. 2020) developed for elementary, middle, and high school agricultural students. The findings presented here are relevant to both public health officials and educators and have implications for reducing populations of competent vectors and nuisance mosquitoes around the home. The following objectives guided this study:

1. Examine elementary students' knowledge acquisition and retention after the educational intervention.
2. Examine middle/high school students' knowledge acquisition and retention after delivery of the educational intervention.
3. Determine if statistically significant differences existed in middle/high school students' attitudes toward using at-home mosquito control practices, attitudes toward the application methods used by vector control agencies, and their perceived importance of mosquito control practices before and after the educational intervention.

Materials and Methods

Population and Sampling

Mosquito-based curriculum was delivered to a total of 809 elementary, middle, and high school students. For the elementary school education portion, we consulted with the County School Board to identify four schools in Marion County, Florida to participate in the study. The lesson was delivered to fourth and fifth grade students at each school (N =272) by the lead author. For the middle and high school education portion, eight student teachers from the University of Florida delivered the mosquito-based curriculum. All student teachers who delivered the mosquito unit had successfully passed their Florida Teacher Certification Examinations prior to delivery of the lessons. Student teachers were also required to attend a two-hour training, prior to delivering the educational unit, to provide instructions and a brief on the materials. The student teachers were instructed to complete one lesson with an activity per class period or day, and student teachers were provided the opportunity to ask questions related to the lessons during this training. Student teachers were then assigned to teach at middle and high schools throughout Florida as part of their internship and delivered the lessons to their students (N = 537). The curriculum was delivered by all teachers within a two-week time frame.

Data from students who did not complete all pre-, post-, and follow-up assessments were excluded from the sample in this study. Responses from students who were administered the incorrect assessment or were not given the assessment within the specified timeframe were also excluded from analyses. For the elementary school, responses from 152 of the 272 elementary students were usable for a 56% response rate. For the middle and high school students, usable responses for the knowledge assessment were collected from 209 of the 537 students, for a 40% response rate; useable data for the attitudinal assessment were collected from 272 middle and high school students, for a 51% response rate. Institutional Review Board (IRB) approval was obtained through the University of Florida (Protocol #IRB201702210) to collect data from elementary, middle, and high school students in Florida.

Lesson Plans and Delivery

Lesson plans were created by the authors and differed between the elementary and the middle/ high school group. Learning objectives and associated educational materials were tailored to the respective age and education level. The lesson plans have been made publicly available at https://preventmosquitoes.org/education/lesson-plans/.

Elementary School

The instructional delivery to fourth and fifth grade students, consisted of one 50-minute lesson which included a supplementary activity tied to multiple learning objectives that addressed Florida Standards for science (i.e., SC.5.N.1, SC.5.N.2, SC.5.L.14, SC.5.L.15, SC.5.L.17, SC.912.N.1, SC.912.N.2, SC.912.L.15, SC.912.CS-PC.3; Florida State University, 2019). The lesson plan was delivered by the corresponding author between October and February of the 2017-2018 academic year. Prior to delivery of the lesson, students completed a pre-test to gauge their knowledge in advance of the instructional delivery. The subsequent presentation was approximately 30-45 minutes (variation due to student participation and questions). The presentation covered the characteristics of insects and their life cycles, basic biology of mosquitoes, and behavior and importance of container mosquitoes. The importance of container elimination to prevent mosquito development was also discussed.

After the conclusion of the presentation, students were provided a bag containing materials associated with a "Fight the Bite" theme, including the following: M&M's®, or Skittles® for students who had chocolate allergies, with the mosquito life cycle printed on them (see Figure 1); pens, pencils, rubber bracelets, and a folder with the "Fight the Bite" slogan on it; a "Fight the Bite" storybook (Allen Wayne Ltd, Vint Hill Farms, VA); and a magnet with a reminder to empty containers holding water once a week (see Figure 2). The folder also contained an activity where a diagram of the mosquito life cycle was provided, but the label for the four life stages were missing. The students were instructed to use their mosquito life cycle M&M's® to fill in the blank parts of the life cycle on the activity sheet. When the student had placed the parts of the mosquito life cycle in the correct location, they were allowed to eat their M&M's®. Students were then given the post-test immediately following completion of the lesson and associated activity.

Figure 1

M&M's® with Mosquito Life Cycles Included in Lesson Plan Materials Packet

Figure 2

Materials Provided to Elementary School Students as Part of the Mosquito Lesson and Activity

Middle and High School

For middle and high school students, a comprehensive instructional unit was delivered by University of Florida student teachers. The instructional unit was composed of four lessons that each included an activity. The four lessons covered the following topics: (1) mosquito biology; (2) source reduction; (3) mosquito-borne illnesses; and (4) mosquito control practices. Guided notes were included to provide student teachers additional information and background to aid their delivery of the lessons. A pre-test was given immediately before the delivery of the four-part instructional unit. The post-test was given immediately following the completion of the entire instructional unit, and the follow-up test was given approximately two to three weeks following the delivery of all four lessons.

Assessments

Knowledge assessments were designed for elementary students and middle/ high school students. All assessments were reviewed for face and content validity by an expert panel consisting of faculty and specialists from the University of Florida Department of Agricultural Education and Communication; Department of Family, Youth, and Community Science; Entomology and Nematology Department; and the Florida Department of Agriculture and Consumer Services. The reading levels of assessments were also reviewed to ensure their appropriateness for the targeted audience. For all assessments, students were asked to answer the questions to the best of their ability and teachers did not help or lead students to correct answers. In combination, the three test scores represent baseline knowledge, post-message knowledge, and the retention of information. Questions were equally weighted for scoring and had only one correct answer.

Elementary School. The knowledge assessment delivered to elementary students included twenty questions designed to assess their general knowledge of mosquito life cycles, biology, and behavior, as well as their knowledge specifically related to container mosquitoes. This assessment was delivered three times to serve as a pre-test, post-test, and final follow-up test. The pre-test was administered prior to the instruction (i.e., lesson and activity), the post-test was administered immediately following the completion of the instruction, and the final follow-up test was administered approximately six weeks following the completion of the instruction.

Middle and High School. The objective knowledge of middle and high school students was assessed using a pre-test prior to delivery of the instructional unit, a post-test immediately following the completion of the unit, and a final follow-up test delivered approximately two to three weeks following the completion of the unit. The pre-test was an abbreviated version of the assessment used for the post- and follow-up tests and included five, multiple choice items to measure students' knowledge of mosquitoes, their life cycle, biology, and control. The assessment used for both the post-test and follow-up test consisted of twenty-five multiple choice questions designed to provide a more extensive assessment of students' knowledge of mosquitoes than the pre-test. In addition to the objective knowledge tests, an attitudinal assessment was developed and administered to the middle and high school students to gauge the effectiveness of the educational intervention on students' attitudes and perceptions related to mosquito control topics. This assessment was administered prior to the delivery of the instructional unit and again two weeks later upon the completion of the unit. Post hoc reliability estimates for the assessment's constructs were calculated using Cronbach's alpha (Cronbach, 1951).

Three sections of the attitudinal assessment were used for data analysis in this study: (a) attitudes toward using at-home methods of mosquito protection and control; (b) perceived importance of using at-home methods of mosquito protection and control; and (c) attitudes toward the application methods used by mosquito control programs to control mosquito populations. Attitudes toward using at-home methods of mosquito protection and control was assessed using a 5-point semantic differential scale between nine sets of descriptors (e.g., bad/good, useless/useful). A construct mean was computed to represent overall attitudes toward using at-home methods of mosquito control. The pre-test internal reliability coefficient for this scale was $\alpha = .92$; the post-test internal reliability coefficient was $\alpha = .88$. Perceived importance of using at-home methods of mosquito control was assessed using four items reflective of the outcomes of mosquito control (e.g., "using at-home methods of mosquito control helps protect me from mosquito-borne illnesses"). Responses were collected using a 6-point Likert-type scale: 1 = *strongly disagree;* 2 = *disagree*; 3 = *slightly disagree;* 4 = *slightly agree;* 5 = *agree;* 6 = *strongly agree*. A construct mean was computed to represent overall perceived importance of using at-home methods of mosquito control. The pre- and post-test internal reliability coefficients for this scale were $\alpha = .90$. Attitudes toward the application methods used by mosquito control programs was evaluated using a 5-point semantic differential scale between nine sets of bipolar descriptors (e.g., unsafe/safe, harmful/beneficial). A construct mean was computed to represent overall attitudes. The pre-test internal reliability coefficient for this scale was $\alpha = .94$; the post-test internal reliability coefficient was $\alpha = .96$.

Data Analysis

Objectives one and two were evaluated using repeated measures analyses. For objective three, paired sample t-tests were employed to compare pre- and post-attitudinal mean scores. A significance level of $p < .05$ was set a priori for both knowledge and attitudinal assessments. Effect size for repeated measures analyses was calculated using partial eta squared, and Cohen's *d* was calculated to report effect size for paired-samples t-test comparisons.

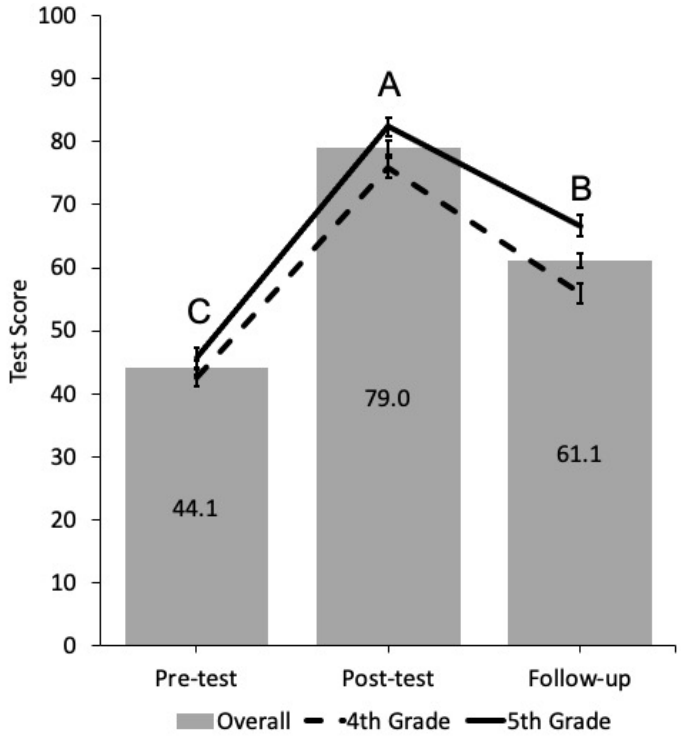
Results

Objective One: Elementary Knowledge Acquisition and Retention

Objective one sought to examine elementary students' knowledge acquisition and retention associated with the lesson plans delivered. The overall mean score for the pre-test was 44.13, the overall mean for the post-test was 78.96, and the overall mean for the follow-up test was 61.1 (see Figure 3). While fourth- and fifth-grade students achieved similar scores on the pre-test, fifth graders scored an average of 6.5 points higher than fourth graders on the post-test. This difference was even more pronounced on the follow-up test, where fifth-grade scores were 10.7 points higher than fourth-grade scores.

Figure 3

Pre-, Post-, and Follow-up Test Scores for Elementary School Students



Note. Bars indicate the average test scores for both 4th and 5th grade students. The dashed line indicates the average test score of 4th grade students and the solid line indicate the average test score of 5th grade students. Differing letters above gray bars indicate a significant difference ($p<.05$) between the overall test scores (N = 152).

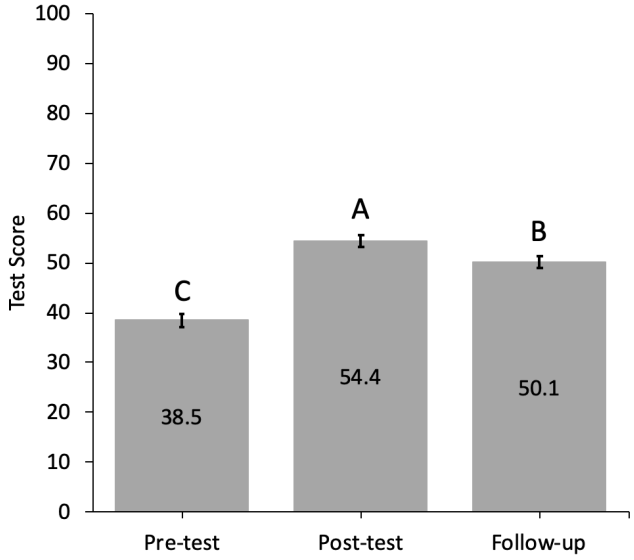
Repeated measures analysis revealed significant differences between students' pre-test, post-test, and follow-up test scores [F (2, 154) = 5.74, p = .004]. On average, students increased their score by 34.83 points when comparing the pre-test to post-test, and they increased their score by 16.97 points when comparing pre-test to follow-up test scores. There was also an interaction observed between test and grade level [F (2, 152) =5.09, p =.007)]. One of the schools where the elementary lesson plans were delivered had significantly lower scores than the other three schools (p=.021, p=.001, p<.0001).

Objective Two: Middle and High School Knowledge Acquisition and Retention

Objective two was concerned with middle and high school students' knowledge acquisition and retention associated with the instructional unit delivered. The overall mean score for the pre-test was 38.47 (*SD* = 19.55). The overall mean score for the post-test was 54.39 (*SD* = 16.16), and the mean for the follow-up test was 50.07 (*SD* = 16.70; see Figure 4).

Figure 4

Pre-, Post-, and Follow-up Test Scores for Middle and High School Students



Note. Differing letters above gray bars indicate a significant difference (p<.05) between the average test scores (N = 209).

Repeated measures analysis revealed that a significant difference existed between students' pretest, posttest, and follow-up test scores. Mauchly's test of sphericity was significant. Therefore, sphericity could not be assumed, and the Greenhouse-Geisser correction to the degrees of freedom was reported for the *F*-test, [F (1.57, 209) = 65.26, p = .000]. On average, students increased their score by 15.92 points when comparing the pre-test to the post-test, and they increased their score by 11.6 points when comparing pre-test to follow-up test scores. The statistical power of the test was 1.0, and partial eta square indicated a large effect size (η_p^2 = .24).

Objective Three: Middle and High School Mosquito Control Attitudes

Regarding changes in attitudes of middle and high school students toward using at-home methods of mosquito control, students in this study demonstrated more positive attitudes after completing the instructional unit (M = 3.90; SD = .90) than before (M = 3.72; SD = 1.23); t (272) = -16.71, p = .025. A small effect size was observed (d = -.31). Statistically significant differences were also observed between students' perceived importance of at-home methods of mosquito control before (M = 4.31; SD = 1.52) and after (M = 4.65; SD = 1.34) the unit of instruction; t (272) = -3.30, p = .001. The effect size for this test was small (d = -.20). Lastly, students demonstrated more positive attitudes toward the application methods used by mosquito control programs after completion of the instructional unit (M = 4.18; SD = 1.33) than before (M = 3.85; SD = 1.24); t (272) = -3.48, p = .001. A small effect size was observed for this test (d = -.21)

Conclusions, Discussion, and Recommendations

Community engagement in mosquito control behaviors can serve as a protective factor and has the potential to reduce the risk of infection with a mosquito-borne disease (Loeb et al., 2005). Further prior research supports the notion that mosquito education efforts can lead to positive changes in desired preventative behaviors, such as container elimination and wearing repellent (LaBeaud et al., 2009; Rigau-Pérez et al., 2002). The goals of this study were to assess the knowledge gain and retention of elementary, middle, and high school students after delivery of an educational message about mosquito control topics. We also assessed the attitudes of middle and high school students toward mosquito control practices and

their importance as a result of the educational unit. The results of this study highlight the potential of the described lesson plans to improve students' knowledge and attitudes toward mosquitoes and mosquito control.

Knowledge Gain and Retention

A dramatic improvement in knowledge about mosquitoes occurred after delivery of the lesson plan(s) for both elementary and middle/ high school students. While some of this knowledge was lost between the initial post-test and the follow-up post-test, students' knowledge levels at the time of the final post-test were still significantly higher than prior to delivery of the lesson plans (see Figures 3 and 4). These findings are consistent with prior research, in which significant improvements in knowledge gain and retention after delivery of a mosquito educational message have been observed (LaBeaud et al., 2009; Madeira et al., 2002; Rigau-Pérez et al., 2002). As such, the results of the current study may provide further evidence of the impact and importance of engaging students in public health-related issues such as preventative measures against vector-borne illnesses.

The greatest change in knowledge acquisition was observed in the elementary group with a ~35-point jump from the pre- to post-test. Intellectual curiosity and enthusiastic learning are considered characteristics of younger students (Ausubel, 1962; Meltzoff et al., 2009). The increased learning ability of younger students, such as that readily seen in language acquisition (Long, 1990), and similar principles may explain the discrepancy in knowledge acquisition and retention observed in our study. It is important to note, however, that elementary and middle/high school students received different lesson(s) and tests to evaluate their knowledge, and the two sets of data are not directly comparable. Future research is needed to identify best methods of designing and delivering instructional lessons and activities in mosquito control education campaigns that foster middle and high school students' curiosity and enthusiasm about the topic.

Further examination of knowledge gains among elementary students revealed differences in the degree of knowledge gained based on grade levels. In our study, a difference in test scores was observed between fourth and fifth grade students, despite being presented identical information, suggesting the materials were better suited for fifth grade students. The observed difference in knowledge acquisition and retention between the elementary grade levels may also be explained by the additional year of biology background and experience of fifth-grade students compared to fourth-grade students. Such differences should be considered when designing and implementing future biology-focused interventions, such as mosquito education campaigns.

Attitudes

After the educational intervention, positive and significant differences were also observed in students' attitudes toward using at-home mosquito control methods, perceived importance of those methods, and attitudes toward mosquito control application methods. The biggest change was observed in the students' attitudes toward mosquito control application methods. Few studies have assessed the impact of educational programs on attitudes toward application methods (Duman-Scheel et al., 2018). In a study conducted in Belize during the Zika epidemic, community stakeholders acknowledged the critical role of mosquito control to tourism in their area, as well as ranked safe and effective solutions as a high priority (Duman-Scheel et al., 2018). Understanding the beneficial role that mosquito control plays in preventing mosquito bites and disease transmission can improve the attitudes of the community toward application methods, a trend that was echoed in our study as demonstrated by improved attitudes after delivery of the mosquito-based curriculum. This is important to consider during epidemics when the impact of community opinion can influence the public health treatments that are conducted (Beaubien, 2016). Based on our study, educational programs can be used to foster positive attitudes toward controversial topics, such as mosquito control.

Additional Recommendations

The acquisition of knowledge and improved attitudes creates the foundation for behavioral changes necessary to employ preventative behaviors, such as container elimination. However, continued application of the concepts learned through the mosquito educational message is critical to retention of that information (Murre & Dros, 2015). Without reinforcement or recall of learned information, students may gradually forget part or all of what they have learned (Murre & Dros, 2015). This can be summarized by the phrase: "if you don't use it, you lose it." Retention of that information can be achieved through repeatedly accessing and utilizing that information (Roediger & Butler, 2011). Knowledge about mosquitoes and preventative practices can be partially or completely lost if it is not practiced or utilized in some way (e.g., educating others). Therefore, students should be taught and encouraged to make a habit of container elimination and other preventative practices to reinforce the initial knowledge gain obtained through the lessons.

Educational Implications

The procedures and results associated with this research study provide implications applicable to community-based education through school-based agricultural education. First, regarding implications for use in school-based education, the improvement in knowledge and attitudes demonstrate potential for positive impacts on youth after exposure to a mosquito-based curriculum. In addition, the instructional units developed as part of this research project addressed several Florida Standards and are publicly available at https://preventmosquitoes.org/education/lesson-plans/. Therefore, these materials can provide elementary, middle, and high school educators in Florida ready-to-implement lesson plans aligned with state standards, as well as provide a starting point for

The results of the current study validate the outreach and educational programs many mosquito control agencies currently deliver. Engaging all members of a community in controlling mosquitoes plays an important role in decreasing biting pressure and protecting human health, and the impact of our educational intervention should be considered among the growing body of literature that demonstrates the effect of community participation against container mosquitoes and how this ultimately impacts public health. The tested curriculum was developed with the goal of being readily implemented into a science or agricultural education classroom. If adopted by the agricultural education classrooms across the country, the reach to the community is expanded by the ~800,000 agricultural education students (Future Farmers of America 2021). Through their familial and social networks, these students have the potential to disseminate the information even further.

The current study is particularly of note when discussing the potential of school-based education as a means of fostering education and engagement among the larger, surrounding community. Prior research supports the notion that increases in knowledge among students can lead to positive behavior change among both the students and their family members (LaBeaud et al., 2009; Rigau-Pérez et al., 2002). LaBeaud et al. (2009) found that family members of students who received a mosquito control educational message positively changed their behaviors to be more preventative against mosquitoes. Similarly, following an educational program in Puerto Rico, the results of focus groups with students' families revealed that the family members had learned about mosquito control methods from observing the students engaging in container elimination activities around their homes (Rigau-Pérez et al., 2002). In our study, elementary, middle, and high school students had a container elimination at-home activity included in their lesson plan (Parker, McLeod-Morin et al., 2020). By completing this at home, students had the opportunity to share their newly acquired knowledge with their families and train them on identifying and eliminating water-holding containers around the home.

Limitations and Sources of Error

A limitation in the presented study was the use of differing pre- and post-test formats for the middle and high school students. The pre-test was an abbreviated version of the post-test and follow-up test, which meant each individual question on the pre-test had a higher scoring value than individual questions on the other two tests. Therefore, one incorrect answer on the pre-test could have greatly affected students' scores. However, based on the trends observed in the elementary school portion of the study, we believe that the knowledge acquisition and retention observed is valid.

References

Ausubel, D. P. (1962). Can children learn anything that adults can-and more efficiently? *The Elementary School Journal*, *62*(5), 270–272. https://doi.org/10.1086/459970

Ballenger-Browning, K. K., & Elder, J. P. (2009). Multi-modal *Aedes aegypti* mosquito reduction interventions and dengue fever prevention. *Tropical Medicine & International Health*, *14*(12), 1542–1551. https://doi.org/10.1111/j.1365-3156.2009.02396.x

Beaubien, J. (2016, August 10). *Puerto Rico's efforts to stop Zika are hampered by mistrust.* NPR. https://www.npr.org/sections/health-shots/2016/08/10/489433636/puerto-ricos-efforts-to-stop-zika-are-hampered-by-mistrust-disease-overload

Bosch, Q. A. ten, Wagman, J. M., Castro-Llanos, F., Achee, N. L., Grieco, J. P., & Perkins, T. A. (2019). Community-level impacts of spatial repellents for control of diseases vectored by *Aedes aegypti* mosquitoes. *BioRxiv*, e501700. https://doi.org/10.1101/501700

Carey, J. M., Chi, V., Flynn, D. J., Nyhan, B., & Zeitzoff, T. (2020). The effects of corrective information about disease epidemics and outbreaks: Evidence from Zika and yellow fever in Brazil. *Science Advances*, *6*(5), eaaw7449. https://doi.org/10.1126/sciadv.aaw7449

Chadee, D. D., & Martínez, R. (2000). Landing periodicity of *Aedes aegypti* with implications for dengue transmission in Trinidad, West Indies. *Journal of Vector Ecology*, *25*(2), 158–163. https://doi.org/10.1111/jvec.12247

Codeço, C. T., Lima, A. W. S., Araújo, S. C., Lima, J. B. P., Maciel-de-Freitas, R., Honório, N. A., Galardo, A. K. R., Braga, I. A., Coelho, G. E., & Valle, D. (2015). Surveillance of *Aedes aegypti*: Comparison of house index with four alternative traps. *PLoS Neglected Tropical Diseases*, *9*(2), e0003475. https://doi.org/10.1371/journal.pntd.0003475

Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. *Psychometrika*, *16*(3), 297–334. https://doi.org/10.1007/BF02310555

Darbro, J., Halasa, Y., Montgomery, B., Muller, M., Shepard, D., Devine, G., & Mwebaze, P. (2017). An economic analysis of the threats posed by the establishment of *Aedes albopictus* in Brisbane, Queensland. *Ecological Economics*, *142*, 203–213. https://doi.org/10.1016/j.ecolecon.2017.06.015

Duman-Scheel, M., Eggleson, K. K., Achee, N. L., Grieco, J. P., & Hapairai, L. K. (2018). Mosquito control practices and perceptions: An analysis of economic stakeholders during the Zika epidemic in Belize, Central America. *PLoS ONE*, *13*(7), e0201075. https://doi.org/10.1371/journal.pone.0201075

Espinoza-Gómez, F., Hernández-Suárez, C. M., & Coll-Cárdenas, R. (2002). Educational campaign versus malathion spraying for the control of *Aedes aegypti* in Colima, Mexico. *Journal of Epidemiology & Community Health*, *56*(2), 148–152. https://doi.org/10.1136/jech.56.2.148

Estep, A. S., Sanscrainte, N. D., Waits, C. M., Bernard, S. J., Lloyd, A. M., Lucas, K. J., Buckner, E. A., Vaidyanathan, R., Morreale, R., Conti, L. A., & Becnel, J. J. (2018). Quantification of permethrin

resistance and kdr alleles in Florida strains of *Aedes aegypti* (L.) and *Aedes albopictus* (Skuse). *PLOS Neglected Tropical Diseases*, *12*(10), e0006544. https://doi.org/10.1371/journal.pntd.0006544

Florida State University (2019). *CPALMS*. https://www.cpalms.org/Public/.

Future Farmers of America (2021). *About FFA: Agricultural education*. https://www.ffa.org/agricultural-education/

Fonseca, D. M., Unlu, I., Crepeau, T., Farajollahi, A., Healy, S. P., Bartlett-Healy, K., Strickman, D., Gaugler, R., Hamilton, G., Kline, D., & Clark, G. G. (2013). Area-wide management of *Aedes albopictus*. Part 2: Gauging the efficacy of traditional integrated pest control measures against urban container mosquitoes. *Pest Management Science*, *69*(12), 1351–1361. https://doi.org/10.1002/ps.3511

Garcia-Sánchez, D. C., Pinilla, G. A., & Quintero, J. (2017). Ecological characterization of *Aedes aegypti* larval habitats (Diptera: Culicidae) in artificial water containers in Girardot, Colombia. *Journal of Vector Ecology*, *42*(2), 289–297. https://doi.org/10.1111/jvec.12269

Hawley, W. A. (1988). The biology of *Aedes albopictus*. *Journal of the American Mosquito Control Association. Supplement*, *1*, 1–39. https://pubmed.ncbi.nlm.nih.gov/3068349/

Healy, K., Hamilton, G., Crepeau, T., Healy, S., Unlu, I., Farajollahi, A., & Fonseca, D. M. (2014). Integrating the public in mosquito management: Active education by community peers can lead to significant reduction in peridomestic container mosquito habitats. *PLoS ONE*, *9*(9), e108504. https://doi.org/10.1371/journal.pone.0108504

Karimi, F., & Visser, S. (2016, September 9). *Zika aerial spraying in Miami completed despite health concerns.* CNN Health. https://www.cnn.com/2016/09/09/health/florida-zika-spraying-starts/index.html

Kittayapong, P., Olanratmanee, P., Maskhao, P., Byass, P., Logan, J., Tozan, Y., Louis, V., Gubler, D. J., & Wilder-Smith, A. (2017). Mitigating diseases transmitted by *Aedes* mosquitoes: A cluster-randomised trial of permethrin-impregnated school uniforms. *PLoS Neglected Tropical Diseases*, *11*(1), e0005197. https://doi.org/10.1371/journal.pntd.0005197

LaBeaud, A. D., Glinka, A., Kippes, C., & King, C. H. (2009). School-based health promotion for mosquito-borne disease prevention in children. *The Journal of Pediatrics*, *155*(4), 590-592.e1. https://doi.org/10.1016/j.jpeds.2009.03.009

Lennon, J. (2004). Students' perceptions about mosquito larval control in a dengue-endemic Philippine city. *Dengue Bulletin*, *28*, 196–206. https://apps.who.int/iris/handle/10665/163965

Liu, H., Cupp, E. W., Guo, A., & Liu, N. (2004). Insecticide resistance in Alabama and Florida mosquito strains of *Aedes albopictus*. *Journal of Medical Entomology*, *41*(5), 946–952. https://doi.org/10.1603/0022-2585-41.5.946

Loeb, M., Elliott, S. J., Gibson, B., Fearon, M., Nosal, R., Drebot, M., D'Cuhna, C., Harrington, D., Smith, S., George, P., & Eyles, J. (2005). Protective behavior and West Nile virus risk. *Emerging Infectious Diseases*, *11*(9), 1433–1436. https://doi.org/10.3201/eid1109.041184

Long, M. H. (1990). Maturational constraints on language development. *Studies in Second Language Acquisition*, *12*(3), 251–285. https://doi.org/10.1017/S0272263100009165

Madeira, N. G., Macharelli, C. A., Pedras, J. F., & Delfino, M. C. N. (2002). Education in primary school as a strategy to control dengue. *Revista Da Sociedade Brasileira de Medicina Tropical*, *35*(3), 221–226. https://doi.org/10.1590/S0037-86822002000300004

McBride, C. S., Baier, F., Omondi, A. B., Spitzer, S. A., Lutomiah, J., Sang, R., Ignell, R., & Vosshall, L. B. (2014). Evolution of mosquito preference for humans linked to an odorant receptor. *Nature*, *515*(7526), 222–227. https://doi.org/10.1038/nature13964

Meltzoff, A. N., Kuhl, P. K., Movellan, J., & Sejnowski, T. J. (2009). Foundations for a new science of learning. *Science*, *325*(5938), 284–288. https://doi.org/10.1126/science.1175626

Murre, J. M. J., & Dros, J. (2015). Replication and analysis of Ebbinghaus' forgetting curve. *PLoS ONE*, *10*(7), e0120644. https://doi.org/10.1371/journal.pone.0120644

Parker, C., McLeod-Morin, A., & Honeycutt, S. (2020). Mosquito education that doesn't suck. *American Entomologist*, *66*(1), 292–295. https://doi.org/1093.ae/tmaa002

Parker, C., Ramirez, D., Thomas, C., & Connelly, C. R. (2020). Baseline susceptibility status of Florida populations of *Aedes aegypti* (Diptera: Culicidae) and *Aedes albopictus*. *Journal of Medical Entomology*, *57*(5), 1550–1559. https://doi.org/10.1093/jme/tjaa068

Rigau-Pérez, J. G., Clark, G. G., Ruiz-Pérez, M., Winch, P. J., Leontsini, E., & Gubler, D. J. (2002). Community-based dengue prevention programs in Puerto Rico: Impact on knowledge, behavior, and residential mosquito infestation. *The American Journal of Tropical Medicine and Hygiene*, *67*(4), 363–370. https://doi.org/10.4269/ajtmh.2002.67.363

Roediger, H. L., & Butler, A. C. (2011). The critical role of retrieval practice in long-term retention. *Trends in Cognitive Sciences*, *15*(1), 20–27. https://doi.org/10.1016/j.tics.2010.09.003

Rogers, E. M. (2010). *Diffusion of innovations* (4th ed.). Simon and Schuster.

Sanchez, L., Perez, D., Pérez, T., Sosa, T., Cruz, G., Kouri, G., Boelaert, M., & Stuyft, P. V. der. (2005). Intersectoral coordination in *Aedes aegypti* control. A pilot project in Havana City, Cuba. *Tropical Medicine & International Health*, *10*(1), 82–91. https://doi.org/10.1111/j.1365-3156.2004.01347.x

Seger, K. R., Roth Jr, J., Schnall, A., Ellis, B., & Ellis, E. (2019). Community assessments for mosquito prevention and control experiences, attitudes, and practices—U.S. Virgin Islands, 2017 and 2018. *Morbidity and Mortality Weekly Report*, *68*, 500–504. https://doi.org/10.15585/mmwr.mm6822a3

Simard, F., Nchoutpouen, E., Toto, J. C., & Fontenille, D. (2005). Geographic distribution and breeding site preference of *Aedes albopictus* and *Aedes aegypti* (Diptera: Culicidae) in Cameroon, Central Africa. *Journal of Medical Entomology*, *42*(5), 726–731. https://doi.org/10.1093/jmedent/42.5.726

Smith, M., Dixon, D., Bibbs, C., Autry, D., & Xue, R.-D. (2018). Diel patterns of *Aedes aegypti* (Diptera: Culicidae) after resurgence in St. Augustine, Florida as collected by a mechanical rotator trap. *Journal of Vector Ecology*, *43*(1), 201–204. https://doi.org/10.1111/jvec.12302

Sommariva, S., Vamos, C., Mantzarlis, A., Đào, L. U.-L., & Tyson, D. M. (2018). Spreading the (fake) news: Exploring health messages on social media and the implications for health professionals using a case study. *American Journal of Health Education*, *49*(4), 246–255. https://doi.org/10.1080/19325037.2018.1473178

Takken, W., & Verhulst, N. O. (2013). Host preferences of blood-feeding mosquitoes. *Annual Review of Entomology*, *58*(1), 433–453. https://doi.org/10.1146/annurev-ento-120811-153618

Unlu, I., Faraji, A., Indelicato, N., & Fonseca, D. M. (2014). The hidden world of Asian tiger mosquitoes: Immature *Aedes albopictus* (Skuse) dominate in rainwater corrugated extension spouts. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, *108*(11), 699–705. https://doi.org/10.1093/trstmh/tru139

World Health Organization. (n.d.). *Mosquito-borne diseases*. http://www.who.int/neglected_diseases/vector_ecology/mosquito-borne-diseases/en/

Yasuoka, J., Mangione, T. W., Spielman, A., & Levins, R. (2006). Impact of education on knowledge, agricultural practices, and community actions for mosquito control and mosquito-borne disease prevention in rice ecosystems in Sri Lanka. *The American Journal of Tropical Medicine and Hygiene*, *74*(6), 1034–1042. https://doi.org/10.4269/ajtmh.2006.74.1034