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Adolescents' Experience and Knowledge of, and Attitudes toward, Bees: Implications and Recommendations for Conservation

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ABSTRACT Invertebrates are generally regarded with apathy, distaste, and fear in Western society. These negative sentiments likely contribute to the disparity in wildlife conservation efforts, which largely favor vertebrate organisms. Bees represent one of the most ecologically and economically important invertebrate groups, yet bee diversity and abundance is declining worldwide, mirroring the general decline of invertebrate biodiversity. Developing and implementing successful conservation efforts requires interdisciplinary research that considers the ecological and social realities of today's world. To better inform conservation efforts related to bees, we examined adolescents' experiences and knowledge of, and attitudes toward, bees and investigated how these dimensions related to one another. A total of 794 eighth-grade science students from the suburbs of Chicago, USA completed a 48-item, paper questionnaire. The results indicated that adolescents were only somewhat knowledgeable about bee biology and services, and they confused bees with other flying insects, especially those with black-and-yellow coloration. Adolescents regarded bees with a generally neutral attitude; their knowledge and attitudes were correlated in a positive manner. Various bee-related experiences were linked to adolescents' knowledge and attitudes and may have influenced bee-related behavior. In particular, students who engaged in gardening and lawn-care activities demonstrated higher levels of knowledge and more positive attitudes. This study provides insight into the relationships between experiences and knowledge of, and attitudes toward, invertebrates and suggests that engaging in certain outdoor activities may promote positive attitudes toward bees among adolescents.

Keywords: bees, insects, education, conservation, attitudes

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The majority of today's biodiversity conservation programs are focused on charismatic vertebrates (Clucas, McHugh, & Caro, 2008). In comparison, invertebrates have received little attention from conservationists (Black, Shepard, & Allen, 2001; Dunn, 2005; Looy & Wood, 2006; Wilson, 1987). Invertebrates often inspire fear and revulsion (Bjerke, Ødegårdstuen, & Kaltenborn, 1998a; Bjerke & Østdahl, 2004; Kellert, 1993; Lorenz, Libarkin, & Ording, 2014), so eliciting support for their conservation can be difficult (Black et al., 2001). Even bees, which are among the most ecologically and economically important invertebrates (Chaplin-Kramer, Tuxen-Bettman, & Kremen, 2011; Klein et al., 2007) are generally disliked by the public (Arrindell, 2000; Bjerke, Ødegårdstuen, & Kaltenborn, 1998b; Bjerke & Østdahl, 2004; Davey, 1994; Snaddon & Turner, 2007). Still, humans have incorporated symbols, myths, and representations of bees into cultural artifacts for thousands of years (Crittenden, 2011; Elderkin, 1939; Hickner & Smith, 2007; Hogue, 2009).

Bees are currently undergoing a global decline in abundance and diversity (Grünewald, 2010; Patiny, Rasmont, & Michez, 2009; Pettis & Delaplane, 2010; Potts et al., 2010). Drivers of bee decline include fragmentation and loss of habitats, pesticides, pathogens, parasites, and invasive species (Grünewald, 2010; Kremen, Williams, & Thorp, 2002; Potts et al., 2010). A variety of conservation strategies have been proposed to stem the declines of bees (Grünewald, 2010; Pettis & Delaplane, 2010) but, as has been seen in other species, understanding people's knowledge and experiences of, and attitudes toward, bees will likely be instrumental in promoting positive conservation behaviors (Fox-Parrish & Jurin, 2008; Glikman, Vaske, Bath, Ciucci, & Boitani, 2012; Prokop, Kubiatko, & Fančovičová, 2008; Snaddon & Turner, 2007).

Thus far, several studies have demonstrated a link between people's knowledge of a species and their attitudes toward that species (Prokop et al., 2008; Prokop, Kubiatko, & Fančovičová, 2009). However, this doesn't always hold true for species associated with danger or physical attack (Prokop, Özel, & Uşak, 2009; Prokop & Tunnicliffe, 2008) . Though bees are responsible for pollinating many global food crops (Klein et al., 2007), they are also capable of inducing anaphylaxis and death in those they sting (Klotz, Klotz, & Pinnas, 2009; Mejia, Arbelaez, Henao, Sus, & Arango, 1986). Furthermore, despite the vast diversity of bee species (Michener, 2007), cultural artifacts predominantly portray bees with yellow-and-black banded coloration (e.g., Hickner & Smith, 2007), which may lead to confusion between bees and their more aggressive counterparts, wasps.

Conservation of bees, and global biodiversity in general, will largely depend on today's adolescents, as they are the future decision-makers (Meinhold & Malkus, 2005). Research suggests that adolescence is the prime developmental stage during which knowledge of and attitudes toward animals can be shaped (Kellert, 1984; Prokop & Tunnicliffe, 2010). Yet today's adolescents are engaging with nature less than previous generations (Louv, 2005), leading to the "extinction of experience," which may further diminish interest in conservation of the environment (Miller, 2005). Inspiring positive conservation behavior toward bees in adolescents (and their future selves) requires an exploration of their knowledge, experiences, and attitudes, as these factors may work to precipitate or inhibit such behavior.

We used a survey questionnaire to explore three broad dimensions of the human–bee relationship as it pertains to eighth-grade adolescents. Our survey was designed to answer the following questions: (1) What types of experiences have adolescents had with bees and the outdoors? (2) What do adolescents know about bees, including identification abilities? (3) What are adolescents' attitudes toward bees? and (4) How are adolescents' experiences, knowledge, and attitudes related to one another? The results of this study can be used to develop or enhance educational programming and curricula that pertain to conservation of bees and other pollinators.

Methods

Participants & Protocol

The study was conducted between May and June of 2013 in the suburbs of Chicago, USA and was approved by the Institutional Review Board of the University of Illinois at Chicago. We invited 20 schools to join the study and seven principals from six school districts agreed to participate. The proportion of low-income students within each school ranged from 6% to 89% of the student population. Three schools had a predominantly Hispanic student population, three were predominantly white (non-Hispanic), and the seventh did not have a racial/ethnic majority.

Nine teachers distributed the survey questionnaire within 41 eighth-grade science classrooms. All students enrolled in participating classrooms were invited to take part, regardless of interest in science or academic standing. Parents and guardians could withdraw their student(s) from the study by signing and returning an *Opt Out* form, which was sent home a week prior to survey administration. Students of consenting parents and guardians could withdraw from the study by leaving the questionnaire blank. Conversely, students consented to participate by voluntarily completing the questionnaire.

A total of 794 students returned completed or partially completed questionnaires. Survey participants included 386 females, 399 males, and nine unidentified grade eight students aged 11 to 15 years. Four teachers self-administered the questionnaire according to a specific protocol, while one of the coauthors administered the questionnaire for the remaining teachers following the same procedure. Students were advised of their rights as participants, reminded that participation was completely voluntary and anonymous, and told that the questionnaire would not be graded or impact the students' standing. Administrators allotted 20 minutes for students to complete the questionnaire.

Survey Instrument

The study instrument consisted of a 48-item paper-and-pencil questionnaire designed for eighth-grade students according to techniques described in Dillman, Smyth, and Christian (2009). Before disseminating the final survey, we modified item structure and content based on performance and feedback from a series of pilot tests completed by seventh-and eighth-grade volunteers with similar sociodemographic backgrounds as prospective participants. The UIC Survey Research Laboratory reviewed the questionnaire and resulting suggestions were incorporated into the final version. The questionnaire required an average of less than 15 minutes to complete and contained three categories of items related to (1) knowledge of bees, (2) attitudes toward bees, and (3) general background information. The full questionnaire is available from the corresponding author upon request.

Knowledge of bees was evaluated based on students' factual understanding of bees and their ability to visually identify bees. We used 16 multiple-choice and true-false items focused on bee biology, ecosystem services, myths, and misconceptions to assess students' factual understanding. Items about bee biology and services pertained to science concepts that students should learn by the end of grade eight, according to state-mandated science standards

(Illinois State Board of Education, 2013). Items concerning myths and misconceptions were derived from issues that arose during pilot testing and commonly held beliefs known to researchers. Each item and possible answer was reviewed for accuracy and plausibility by an experienced entomologist. Answers to each item included an "I don't know" option, in order to limit guessing. Answers were scored as correct (1) vs. incorrect or "I don't know" (0). We assessed individuals' factual understanding by dividing number of correct responses (range 0 to 16) by total number of items (n = 16), with unanswered items scored as zero.

We assessed students' ability to identify bees using binary selection items. Students evaluated life-sized, color images of eight flying insects and determined which images were of bees and which were not, thereby visually differentiating bees from other insects. The images included four morphologically diverse bee species: a honey bee (*Apis mellifera*), carpenter bee (*Xylocopa sp.*), sweat bee (*Agapostemon sp.*), and bumblebee (*Bombus sp*.). We also selected four other flying insects with yellow and black coloration: three wasp species common to the Midwest [yellow jacket (*Vespula sp*.), Eastern cicada killer (*Sphecius speciosus*), and paper wasp (*Polistes sp*.)] and a bald-faced hornet (*Dolichovespula maculate*). Students selected "Yes, this is a bee" or "No, this is not a bee" for each image, and the answers were scored as correct (1) vs. incorrect (0). An "I don't know" option was omitted in an attempt to imitate judgments made when encountering a real flying insect. We assessed individuals' abilities to visually identify bees by dividing number of correct responses (range 0 to 8) by total number of items (n = 8), with unanswered items scored as zero. We produced a composite knowledge score by dividing students' combined number of correct responses to factual understanding and visual identification items (range 0 to 24) by total number of knowledge items (n = 24).

Attitudes toward bees were gauged via student responses to a series of 19 statements that varied in content from general characterizations of bees to hypothetical situations involving bees (Table 1). Students evaluated each statement using a 5-point, Likert-style response that ranged from "strongly disagree" (1) to "strongly agree" (5). We assessed an individual's attitude toward bees by averaging responses (range 1 to 5) to all statements. Negatively formulated statements (i.e., "Bees are dangerous") were scored in reverse order to maintain a unidirectional scale. A high average attitude score indicated positive attitudes toward bees, while a low score indicated negative attitudes. We calculated a Cronbach's alpha coefficient of 0.85 for the attitude-related items, indicating an acceptable level of internal consistency, and thus reliability (Nunnaly, 1978).

Questionnaire items about students' backgrounds inquired about bee-related experiences, outdoor activities, and sociodemographic characteristics. For example, we asked whether students had seen *Bee Movie*, had been stung by a bee, were allergic to bee stings, or had attempted to save or kill a bee. We also collected information regarding the outdoor activities students engaged in (i.e., playing sports, gardening, etc) and the amount of time students spent outside in the two weeks prior to completing the questionnaire. Finally, students responded to items about their sex, race/ethnicity, and parental education level. Percentage of students who selected each response item was calculated out of total number of respondents to that item rather than total number of students.

Analysis

Despite our large dataset, not all variables were normally distributed. Rather than transform variables for analysis, we used non-parametric tests when appropriate. We used Pearson product-moment correlations to assess relationships between knowledge and attitude,

Table 1. Students were asked to indicate their level of agreement with the following statements, which were intended to assess students' attitudes toward bees. Possible responses ranged from "strongly disagree" (1) to "strongly agree" (5). A copy of the full questionnaire is available from the corresponding author upon request.

Statements about Bees
If a bee came near me while I was eating outside, I would ignore the bee until it left.
I would want to destroy a bee's nest built very close to my home.
If I had a garden, I would want to plant flowers that attract bees.
When a bee comes near me, I feel tense.
If I were walking down a street and noticed a bee on a flower, I would stop to look at it.
I would want to destroy a bee's nest built in a public park.
If a bee came near me while I was reading outside, I would ignore the bee until it left.
If I had a garden, I would want to remove flowers that attract bees.
If I found a bee inside of my home, I would want to kill it.
Bees are dangerous.
Bees are an important part of nature.
When a bee comes near a friend of mine, I feel tense.
Bees need to be protected by humans.
It is okay to kill a bee if it is flying near you.
Bees are annoying.
I would not care if bees went extinct.
Bees are interesting.
It is okay to kill a bee if it will not leave you alone.
We should learn more about bees in school.

allowing us to ask whether students who know more about bees have more positive attitudes toward them. We used Mann-Whitney rank-sum tests or *t*-tests (depending on data normality) to compare students' experiences in light of these dimensions (e.g., Do students who garden have more positive attitudes toward bees?). When differences were significant, we measured effect size with Cohen's d (for t-tests) or r (for Mann-Whitney tests); $d \approx 0.2$ or $r \approx 0.1$ is considered a small effect, $d \approx 0.5$ or $r \approx 0.3$ is considered a medium effect, and $d > 0.8$ or $r > 0.5$ is considered a large effect. Finally, we employed chi-square tests and two-way ANOVAs to examine the role of gender in experiential differences (e.g., Are female or male students more likely to be stung by a bee?). Statistics were performed using R 3. 0. 2 and SigmaPlot 11.0.

Results

Knowledge

Students answered an average of 53% ($SD = \pm15\%$, range 6–94%) of the knowledge items correctly. There was no significant difference between genders ($p = 0.156$). The majority of students exhibited high proficiency in basic bee biology, with 97% correctly classifying bees as insects and 93% correctly identifying bees as most active during warmer months. Students also demonstrated an understanding of the pollination services provided by bees: 79% recognized that bees carry pollen between flowers, and 84% cited bees as responsible for

Table 2. Percentage of students that correctly identified images of bees and incorrectly identified images of non-bee insects as bees.

Type of Insect	Selected Answer: "Yes, this is a bee"
Bee	(Correct)
Honey bee *Apis mellifera*	97%
Bumblebee *Bombus sp*	95%
Carpenter bee *Xylocopa sp.*	54%
Sweat bee *Agapostemon sp.*	18%
Non-bee	(Incorrect)
Yellow jacket *Vespula sp.*	76%
Paper wasp *Polistes sp.*	69%
Eastern cicada killer *Sphecius speciosus*	35%
Bald-faced hornet *Dolichovespula maculata*	20%

pollinating many garden flowers. However, only 36% of students recognized that transporting pollen allows flowers to reproduce as opposed to allowing them to obtain nutrients (28%) or photosynthesize (17%). Under half (49%) correctly characterized the relationship between bees and flowers as mutualistic.

Students' responses identified common myths and misconceptions. For example, only 53% of students correctly identified honey bees as producers of the honey purchased in stores, while 62% incorrectly asserted that most bee nests hang from tree branches. Similarly, more than half (60%) of students either incorrectly believed that bees carry diseases capable of infecting humans or do not know. Furthermore, students were almost equally divided on whether bees always die after stinging a person, with 39% incorrectly saying bees always die and 42% correctly saying that they do not always die.

When asked to visually identify a selection of flying insects as bees or not bees, students answered an average of 58% ($SD = \pm 17\%$; range 12.5–100%) of items correctly. Nearly all students (97%) correctly identified the honey bee as a bee, but more than three-fourths of the students (76%) incorrectly identified the yellow jacket as a bee as well (Table 2). On average, males correctly identified one more insect (62.5% of items) than females (50% of items), ($U = 62165.5$; $p < 0.001$; $r = 0.17$). The two elements of students' knowledge—factual understanding and ability to identify bees—correlated in a weak but positive direction ($r_{(792)} = 0.15$; $p < 0.0001$).

Attitudes

Overall, students demonstrated a neutral attitude toward bees. Males ($M = 3.05$) demonstrated slightly more positive attitudes than females ($M = 2.91$), ($t_{(782)} = -3.13$; $p = 0.002$; *Cohen's* $d = 0.17$).

Experiences

Over 75% of students reported spending more than five total hours outside in the previous two weeks, with 36% of students spending more than 10 hours outside. Only 49 students reported spending fewer than two hours outside in the same period. Gardening, described as planting flowers/vegetables, watering outdoor plants, or pulling weeds, was the least popular outdoor activity overall (Figure 1), but more common among females (29%) than males (15%),

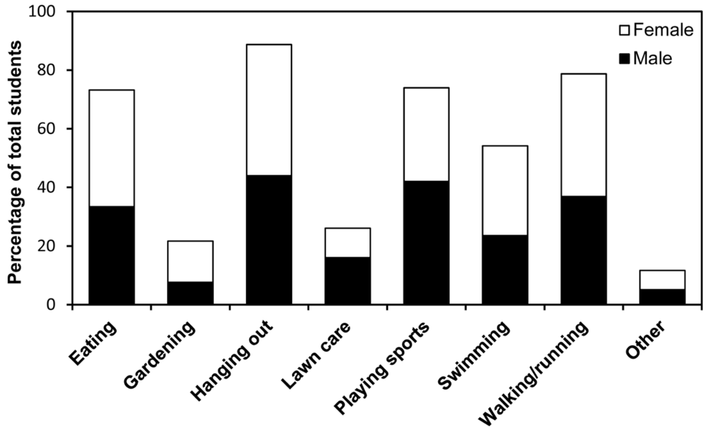

Figure 1. Percentage of female and male students who reported participating in specific outdoor activities throughout the year.

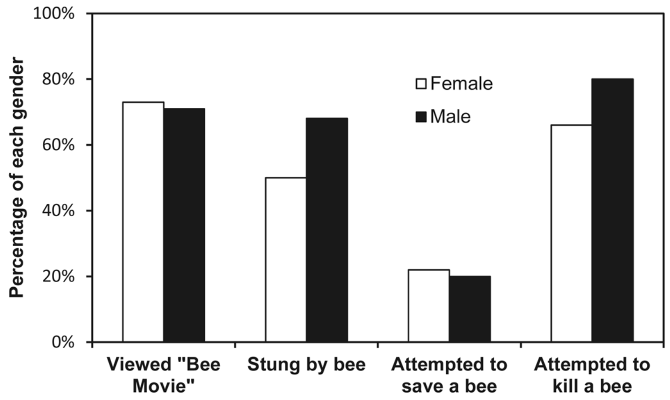

Figure 2. Percentage of female and male students that reported bee-related experiences. Males were more likely than females to have been stung by a bee ($p < 0.001$) and to have attempted to kill a bee ($p < 0.001$). There were no other gender differences.

($\chi^2 = 20.02$, $df = 1$; $p < 0.001$). Conversely, 32% of males reported performing lawn care (e.g., raking leaves or mowing grass), compared to just 21% of females ($\chi^2 = 11.89$, $df = 1$; $p < 0.001$).

Of bee-related experiences, more than two-thirds (67%) of students indicated they had seen *Bee Movie*, and over half (57%) had been stung by a bee. While 72% of students had attempted to kill a bee in the past, only 21% ever tried to save a bee. Male students were more likely to report being stung by a bee and having tried to kill a bee than female students (Figure 2). Only 5% of students reported an allergy to bee stings, though nearly 25% of students were unsure of having an allergy. Eleven students reported allergies to bee stings despite also reporting that they had never been stung or were uncertain about having been stung.

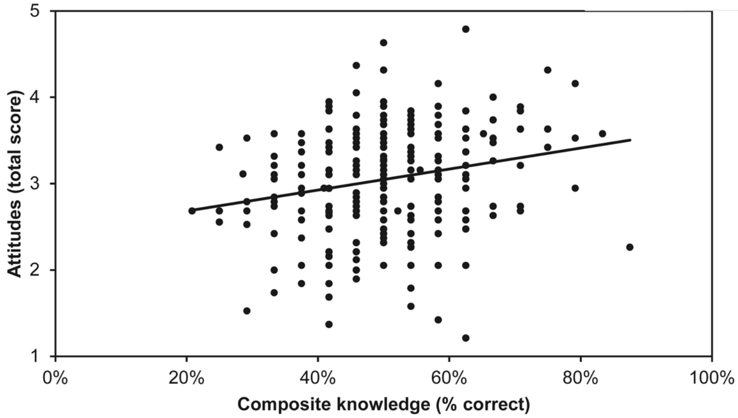

Figure 3. Relationships between attitudes toward bees and composite knowledge of bees ($r_{(791)} = 0.23$, $p < 0.001$).

Relationships between Experience, Knowledge, and Attitude

Greater knowledge of bees, including factual understanding and visual identification, was associated with more positive attitudes toward bees ($r = 0.23$, $p < 0.001$, Figure 3). Students who reported seeing *Bee Movie* did not differ in factual understanding ($p = 0.666$) or ability to identify bees ($p = 0.856$) from those who did not see the movie; however, students who viewed Bee Movie demonstrated a more positive attitude toward bees ($M = 3.038$) than others ($M = 2.834$) ($t_{(732)} = 3.971$; $p < 0.001$; $d = 0.33$). Attitudes toward bees did not differ between students who had been stung by a bee and those who had not ($p = 0.208$), but those who had been stung were more likely to attempt to kill a bee (77%) than those who had not been stung (70%) ($\chi^2 = 9.68$, $df = 1$; $p = 0.002$). On average, students who reported trying to save a bee demonstrated a more positive attitude ($M = 3.42$) than those who had not tried to save a bee ($M = 2.89$) ($U = 26460.50$; $p < 0.001$; $r = 0.34$). Similarly, students who reported trying to save a bee demonstrated a higher level of factual understanding ($M = 56.3\%$) ($U = 43337.00$; $p = 0.001$; $r = 0.11$), and better ability to identify bees ($M = 62.5\%$) ($U = 46266.50$, $p = 0.035$, $r = 0.08$) than their counterparts ($M = 50\%$ each). Students who reported trying to kill a bee held more negative attitudes ($M = 2.87$) than those who had not ($M = 3.26$) ($t_{(786)} = -7.93$; $p < 0.001$; $d = 0.63$). While there was no statistical difference in factual understanding between those who had or had not tried to kill a bee ($p = 0.161$), students who reported trying to kill a bee had a poorer ability to identify bees ($M = 50\%$) compared with others ($M = 62.5\%$) ($U = 52871.50$; $p < 0.001$; $r = 0.11$).

We assessed how outdoor experiences related to students' knowledge of and attitudes toward bees. There was no correlation between the amount of time students spent outside and their factual understanding about bees ($r = 0.003$; $p = 0.94$), their ability to identify bees ($r = -0.01$; $p = 0.75$), or their attitude toward bees ($r = 0.05$; $p = 0.17$). However, particular outdoor activities were related to students' knowledge and attitudes. Students who reported participating in gardening activities held slightly more positive attitudes toward bees ($M = 3.16$) than non-gardening students ($M = 3.00$) ($U = 44075.50$; $p < 0.001$; $r = 0.13$). Gardening students also demonstrated a slightly higher level of factual understanding ($M = 56.3\%$) than

Table 3. Two-way analysis of variance (ANOVA) of adolescents' attitudes toward bees.

	df	SS	MS	*F*	*p*
Gardening					
Gender	1	4.833	4.833	12.503	< 0.001
Gardening	1	6.534	6.534	16.902	< 0.001
Gender × Gardening	1	0.265	0.265	0.684	0.408
Residual	780	301.526	0.387		
Lawn Care					
Gender	1	1.793	1.793	4.585	0.033
Lawn Care	1	3.015	3.015	7.709	0.006
Gender × Lawn Care	1	0.117	0.117	0.298	0.585
Residual	780	305.041	0.391		

non-gardening students ($M = 50\%$) ($U = 48467.00$; $p = 0.039$; $r = 0.07$), though gardening was not related to students' ability to visually identify bees ($p = 0.253$). Similar to gardening, students who reported engaging in lawn-care activities held more positive attitudes toward bees ($M = 3.16$) than those who did not ($M = 2.95$) ($U = 51040.50$; $p < 0.001$; $r = 0.12$). Both factual understanding ($U = 46358.00$; $p < 0.001$; $r = 0.18$) and ability to identify bees ($U = 55305.50$; $p = 0.048$; $r = 0.07$) differed among students who performed lawn care ($M = 56.3\%$ and 62.5%, respectively) and those who did not ($M = 50\%$ each). A two-way ANOVA indicated no significant interactions between gender and gardening or gender and lawn care on students' attitudes (Table 3).

Discussion

An important step toward conserving Earth's biodiversity is to understand the relationships between humans and nature, especially as it pertains to the effects of knowledge and attitudes on behavior (e.g., Aipanjiguly, Jacobson, & Flamm, 2003; Barney, Mintzes, & Yen, 2005). We investigated the link between these dimensions with regard to bees, a sometimes charismatic, sometimes troublesome, group of species that provides vital ecosystem services (Klein et al., 2007). Students' knowledge of bees correlated positively with their attitudes toward bees. Building students' knowledge of bees may then help promote positive attitudes toward bees. Alternatively, students who have already formed positive attitudes toward bees may be more likely or willing to augment their knowledge.

Students' factual understanding of bees was generally mediocre and not significantly different between males and females. Students proved knowledgeable of basic biological facts such as taxonomic identification, seasonal activity patterns, and diet composition, but failed to demonstrate a more in-depth understanding of bee behavior and services. For example, most students identified pollen as the substance bees carry between flowers and labeled this activity "pollination" (both basic biological facts), but far fewer students understood that this activity enables plant reproduction. These findings suggest students have a superficial understanding of pollination and are largely unaware of bees' functional role within ecosystems. Similarly, only about half of students recognized that the honey consumed by humans is produced by honey bee species, further highlighting students' lack of understanding of bee services.

The sources of students' factual understandings, including misconceptions, remain unclear. Formal schooling, informal educational experiences, personal experiences, and cultural artifacts are all potential sources of knowledge (Patrick et al., 2013; Prokop, Prokop, Tunnicliffe, & Diran, 2007; Tunnicliffe & Ross, 1999). For example, the belief that most bee nests hang from trees may originate in personal observations of nests of wasps and bald-faced hornets, which can be conically shaped and hang from tree branches (Frye & Alpert, 2014). Alternatively, this misunderstanding of nesting behavior may have been gleaned from cultural artifacts such as cartoon portrayals of Winnie the Pooh harvesting honey from low-hanging bee nests. Regardless of the source of the misunderstanding, students who incorrectly believed that most bee nests hang from trees did not did differ from students who answered the question correctly in their ability to identify bees.

Having seen *Bee Movie* did not impact students' factual understanding of bees, but this does not preclude other cultural artifacts from impacting students' perceptions, especially if they are viewed repeatedly, as may occur with commercials (i.e., Honey Nut Cheerios®). Students' misconceptions require perhaps the greatest attention, as misconceptions can be deeply ingrained and difficult to rectify after time (Vosniadou, Vamvakoussi, & Skopeliti, 2008).

Cultural artifacts may play a role in students' ability to correctly identify bee species as well. Honey bees and bumblebees, both of which possess black-and-yellow banded coloration, were correctly identified as bees by the vast majority of students. Carpenter bees and bumblebees resemble one another in size and shape, but the carpenter bee in the questionnaire was entirely black in color and was identified as a bee by just over half of students. Sweat bees are smaller than the other featured bees, with a distinct, iridescent green coloration; only 18% of students identified the sweat bee as a bee. Given the low rate of identification for non-black-and-yellow bees, especially given the decrease in positive identification between the otherwise similar carpenter bee and bumble bee, it appears that many students relied on coloration to positively identify bees.

A similar pattern of identification based upon coloration was found among wasps and hornets. A large portion of students misidentified yellow jackets and paper wasps, the two wasp species most resembling the quintessential bee in size, shape, and coloration. The eastern cicada killer wasp, however, is considerably larger, with less pronounced yellow markings, and was misidentified as a bee by fewer students. Finally, the bald-faced hornet, a predominantly black insect, was misidentified as a bee by an even smaller proportion of students, despite being a relatively similar size to the yellow jacket.

Since bees are rarely, if ever, represented as morphologically diverse in popular culture, the tendency to identify black-and-yellow banded insects as bees may derive from experiences with the quintessential bee in cultural artifacts. Due to time constraints within classrooms, we chose to focus on students' abilities to distinguish bees from other insects within the order Hymenoptera; however, future studies may benefit by incorporating non-flying insects with similar black and yellow coloration to determine how important insect shape and the presence of wings are to correct identification. In a study of elementary school children in Slovakia, 1/3 of children misidentified bats as birds because both possess wings (Prokop, Kubiatko, & Fančovičová, 2007).

Overall, students expressed a positive-leaning, but generally neutral attitude toward bees. However, students with more difficulties identifying bees exhibited more negative attitudes toward bees, which may be a result of confusing bees with their more aggressive counterparts (Antonicelli, Bilò, & Bonifazi, 2002), wasps. In our study, males generally held more positive attitudes than females, concurring with previous research about male and female adolescents' attitudes toward invertebrates and insects in general (Bjerke et al., 1998a; Prokop, Tolarovičová, Camerik, & Peterková, 2010; Prokop & Tunnicliffe, 2008; Snaddon & Turner, 2007), and bumblebees in particular (Bjerke et al., 1998a). Previous research on adults did not find a gender difference in attitude toward bees, though females remained more fearful of wasps than males (Davey, 1994). Considering females in our study demonstrated poorer identification abilities and more negative attitudes than males, it may be that females learn to differentiate bees from wasps by the time they reach adulthood, resulting in similar adulthood attitudes as males.

Davey (1994) suggested being stung may act as a conditioning experience that provokes fear of bees (and wasps) and negative attitudes. Just over half of our students reported being stung by a bee, but those that were stung did not differ from other students in attitudes toward bees. Moreover, if stings did act as a conditioning experience, we would have expected males to have more negative attitudes toward bees because they reported being stung more often than females. Instead, males demonstrated more positive attitudes than females. Thus, being stung does not appear to precipitate negative attitudes for these adolescents, although students who had been stung were more likely to have attempted to kill a bee. While we did not ask this question of students, it is possible that their attitudes toward bees could also be influenced by their preferences for honey.

Students who had attempted to kill a bee also expressed more negative attitudes toward bees and demonstrated a poorer ability to identify bees. It is possible, then, that attempts to kill bees are precipitated not by bees themselves, but by misidentified wasps. These interactions may breed negative attitudes within adolescents, who mistakenly assign the blame to bees. If these attitudes and behaviors are carried into adulthood, they may manifest in negative bee-related behavior (e.g., active extermination of bees, use of pesticides), rather than the positive behaviors necessary for bee conservation (e.g., planting pollinator-friendly gardens).

Gardening and lawn-care activities may promote knowledge of bees and foster positive attitudes toward bees, which may subsequently influence behavior. However, it is also possible that students with positive views toward nature (whether intrinsic or parent-inspired) are more inclined to garden or perform lawn care. School gardens provide the opportunity for students to engage in experiential learning (Blair, 2009) and may provide a structured environment in which to engage students in gardening and lawn-care activities. School gardens can enhance science achievement in younger students (Klemmer, Waliczek, & Zajicek, 2005) and other outdoor education programs can increase positive attitudes about biology in general and plants in particular (Fančovičová & Prokop, 2011). As an extension of outdoor activities, schools might also invest in self-contained, secure observation beehives within classrooms. Observation beehives have a port to the outdoors, allowing honey bees to venture outdoors and return to their nest within the classroom where students can directly and safely observe them (e.g., "Classroom Observation Hives," http://www.classroomhives.org/). Similar classroom activities incorporating direct observations of living spiders decreased students' fear of the arthropods (Wagler & Wagler, 2014). The potential for school gardens and observational beehives to provide meaningful engagement with bees (i.e., propagation of student-planted flowers and crops) has yet to be investigated, though such in-school and after-school activities have the potential to influence students' knowledge, attitudes, and behaviors.

In summary, the successful conservation of bees will largely depend on adolescents, the world's future decision-makers (Meinhold & Malkus, 2005). Improving students' knowledge of bees may inspire more positive attitudes toward bees and motivate positive conservation behaviors. Correcting students' misconceptions, especially those pertaining to the roles bees play within ecosystems, and helping students to differentiate bees from wasps will likely move students toward becoming more knowledgeable, bee-friendly adolescents, and eventually adults. Through informed, educational programming, we have the opportunity to inspire the conservation of bees within adolescents so that in the future they may display the knowledge and sentiments already shared by one of our participants, who stated: "I love bees so much! I think they are really cute and adorable and I really wish bees would stop being killed because we need them in our life … "

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Conflicts of Interest

The authors state there are no conflicts of interest

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