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Research article

Testing the effect of aquarium-based learning on patron acceptance of evolutionary theory

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Abstract

Public rejection of science has long been a concern of the scientific community and has the potential to cause great societal harm. Using public acceptance of evolutionary theory as the model, this study set out to examine if zoos and aquariums could address this issue using methods known to increase evolutionary acceptance in formal education settings. The data were obtained at the Aquarium of Boise (Idaho, USA), where participants (n=64) completed a two-part survey and participated in a 15-min presentation. The first half of the survey asked various demographic questions, along with questions that measured their openness, acceptance and belief of the theory of evolution. Participants then participated in a live animal presentation that presented the theory of evolution in a way known to increase acceptance in a formal educational setting. Following the presentation, participants were directed to answer the second half of the survey asking them to reevaluate their openness, acceptance and belief of evolutionary theory. The research showed a significant number of individuals ($P<0.001$) shifted towards a more positive view of evolutionary theory. The regression model was able to significantly predict initial view of evolution ($F(1206303.081, 241260.616)=4.874$, $P<0.001$, $R^2=0.296$), but there is nothing that correlates with a propensity to shift towards a more positive view of evolution. Thus, this study shows that it is possible for zoos and aquariums to use techniques found to be effective in formal educational settings to increase public acceptance of controversial scientific topics.

Introduction

Disconnect between public opinion and scientific reality is an international quandary. The scientific community has warned about the dangers of scientific illiteracy and proposed countermeasures for decades (Bishop 1989; Augustine 1998; Liu 2016; Snow and Dibner 2016; Pasek 2017). Despite prolonged efforts by the scientific community, this is still a major issue. For example, a Pew Survey found that only 49% of Americans said that human activity contributes a great deal to climate change (Pew 2019b); less than half of Americans (47%) believed that medical scientists "[understood] very well the risks and the benefits of the MMR vaccine" (Pew 2017b), and about half of Americans said genetically modified foods would create environmental and health problems (Pew 2016).

The danger of public rejection of science has been put in the spotlight with the recent rampant spread of misinformation relating to the novel coronavirus COVID-19 (Adams 2020; Frenkel et al. 2020; 'Misinformation will undermine coronavirus responses' 2020; Ritchel 2020). Because zoos and aquariums host 700 million visitors annually (Gusset and Dick 2011), there is reason to believe that they are in a powerful position to combat scientific denialism (Barongi et al. 2015; Pavitt et al. 2019). Zoos and aquariums have long recognised that providing public education is vital to achieving their conservation mission (Conway 1969; Hutchins and Smith 2003). A mission statement analysis highlighted this theme by revealing that out of the 136 zoo mission statements analysed, 131 mentioned the theme of education (Patrick et al. 2007). Research has suggested that, to some extent, zoos and aquariums have been successful in

shifting public opinion. Pavitt et al. (2019) tested a zoo's abilities to relay conservation messages and facilitate educational thought. Their study specifically focussed on walk-through exhibits and the role of zoo employees in public education and found that these educational methods left patrons with a greater understanding of the factors surrounding conservation. The current research focuses on the potential for zoos and aquariums to increase acceptance of evolutionary theory specifically.

State of evolution acceptance

Public acceptance of evolution remains low in many parts of the world. In a 2017 survey, nearly 38% of Americans responded that they believed that God created humans in their current state within the last 10,000 years (Swift 2017), although this number drops to 19% if the question is asked differently (Pew 2019a). A Pew research poll (2017a) asked respondents if they agreed that God created humans in their "present form in the beginning", and 26% of Russians, 29% of Greeks, and 56% of Armenians agreed. For many people of a variety of faith traditions, the theory of evolution can be a cause of tension between science and their world view (Lamoureux 2008). Consequently, advocates for the scientific community often highlight the need for improved education to change public opinion (Baker 2013).

Methods for increasing acceptance

Deficit thinking

A common approach for increasing the acceptance of evolutionary theory focuses on teaching the facts of evolution. Educators who implement this ideal expect that there is a correlation between knowledge and acceptance. Over the years, studies on the efficacy of teaching the facts as a means of increasing acceptance of evolutionary theory have yielded varying results. A series of more recent studies has suggested a well-supported positive relationship between knowledge of evolution and its acceptance (e.g., Rissler et al. 2014; Glaze et al. 2015; Dunk et al. 2017; Weisberg et al. 2018). However, a portion of the literature has found no correlation (e.g., Bishop and Anderson 1990; Brem et al. 2003; Sinatra et al. 2003; Nehm and Schonfeld 2007; Chinsamy and Plagányi 2008; Hasan and Donnelly 2011; Mead et al. 2017). While the available data is inconclusive, it is reasonable to assume that knowledge plays an interactive role in acceptance of evolutionary theory.

While the relationship between the understanding of the facts of evolution and acceptance of Darwin's theory has varying support in the literature, a similar approach of viewing those who reject evolution as having a deficit reasoning capacity, and viewing them as a "lost cause" (e.g., Lawson and Weser 1990; Honey 2015) does not. Unproven claims and polarising statements imply that a rejection of evolution is the result of lower cognitive aptitude and unintelligence (Lindsay 2019). For example, evolutionary biologist Richard Dawkins (1989) controversially stated: "It is absolutely safe to say that if you meet somebody who claims not to believe in evolution, that person is ignorant, stupid or insane" (p. 34). Anecdotally, this mindset has been found to be unsuccessful in changing attitudes toward acceptance of evolution.

Teaching the facts of evolution is a good starting point and is likely a necessary method in increasing acceptance of evolution. However, the relationship between knowledge and acceptance appears to be influenced by a number of external factors aside from understanding. These factors include religious beliefs and background (Dagher and BouJaoude 1997; Miller et al. 2006; Deniz et al. 2007), views about the nature of religion (Winslow et al. 2011), and pressure from parents (Winslow et al 2011). In fact, several studies agree that those who hold a literal interpretation of scripture are more likely to reject evolution (Berkman and Plutzer 2010; Baker 2013; Hill 2014). For many religious people, learning about what evolution is will not be enough for them to accept it. Many may still see the theory of evolution as threatening to their religion even after learning the details of the process. Additional methods of teaching are often necessary.

Emphasising the nature of science

Another approach used to teach evolution is to focus on the nature of science (NOS). The National Science Teachers Association explains that "although no single universal step-by-step scientific method captures the complexity of doing science, a number of shared values and perspectives characterize a scientific approach to understanding nature". Among these are a demand for naturalistic explanations supported by empirical evidence that are, at least in principle, testable against the natural world. Other shared elements include observations, rational argument, inference, skepticism, peer review and reproducibility of the work. This characteristic of science is also a component of the idea that 'science is a way of knowing' as distinguished from other ways of knowing (National Science Teachers Association). Studies with high school biology teachers (Rutledge and Warden 2000) and undergraduate students (Lombrozo et al. 2008) revealed significant relationships between an understanding of NOS and the acceptance of evolutionary theory (Akyol 2010). Especially for religious individuals, an understanding of the differences between the purposes of science and religion can have a large impact on acceptance of evolution (e.g., Cavallo and McCall 2008; Cofré et al. 2017; Dunk et al. 2017). Thus, teaching an understanding of how science is conducted, and what it can and cannot explain, is an excellent starting point for increasing acceptance.

Reconciliation

Teaching the facts of evolution and emphasising the nature of science can have a powerful effect on many people in their acceptance of evolution. Many others, especially those with high religiosity, may not be convinced as simply. "Arriving at the belief that the Lord employed evolution as His creative method is not only challenging but also takes time" (Lamoureux 2008). A reconciliation model (helping individuals see that evolutionary theory is compatible with their religious faith or world view) of evolutionary acceptance can have a great impact on those who hold their faith in high regard. This approach is well summarised by world-renowned ecologist E.O. Wilson: "Science and religion are the two most powerful forces in the world. Having them at odds ... is not productive" (PBS 2007). In practice, this model typically includes a discussion of how evolution can fit within one's religious beliefs or world view (Lindsey et al. 2019) and an example of role models of a similar faith or world view who were able to reconcile evolution with their beliefs (Barnes and Brownell 2017; Holt et al. 2018). This approach can result in rapid change. For example, a Pew survey (2019a) found that the number of respondents who expressed creationists views dropped from 31 to 18% when respondents were able to clarify that they believed God played a role in human evolution.

There are barriers to this approach. Only 10% of evolutionary biologists self-report as being religious (Graffin and Provine 2007), while 80% of the American population reports a belief in God (Pew 2018). Clearly there is a potential disconnect between educators and their audience. Additional studies have shown that religiosity correlates with rejection of evolutionary theory more than any other factor (Dagher and BouJaoude 1997; Hill 2014; Rissler et al. 2014). Research performed on this topic suggests that a reconciliatory model leads to a significant increase in student acceptance of evolution without diminishing their religious conviction (Manwaring et al. 2015; Barnes and Brownell 2017; Lindsay 2019).

This paper describes the current state of evolution acceptance, the methods found to be effective ways of increasing acceptance

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Table 1. Summary of Population Demographics

Variable					
Denomination	Protestant (37.88%)	Non-affiliated (27.27%)	CJCLDS (Mormon) (16.67%)	Catholic (15.15%)	Other (3.03 %)
Age	18-30 (22.06%)	31-40 (42.65%)	41-50 (16.18%)	51-70 (14.70%)	71+ (4.41%)
Education	Some high school (1.45%)	High school (15.94%)	Some college (26.09%)	Bachelor's degree (28.99%)	Advanced degree (27.54%)
Religiosity	< 10 (2.86%)	11-20 (20.00%)	21-30 (25.71%)	31-39 (24.29%)	40 (27.14%)
Political affiliation	Independent (33.82%)	Republican (30.88%)	Democrat (29.41%)	Non-affiliated (5.88%)	

amongst undergraduate students and discusses how similar approaches could be used in a public setting to increase scientific literacy in other subjects.

Materials and methods

Implied consent

Permission for this study was obtained from the primary author's institutional review board, and directly from the executive director of the Aquarium of Boise. Subjects were informed that their responses were part of a research study and were asked for implied consent by returning their surveys.

Animal welfare

Although animals were not the subject of this study, animals were used as part of the presentation. Care was taken to minimise any potential discomfort to animals during the presentations.

Venue selection and recruitment

To determine whether effective teaching strategies can shift public opinion of evolution, data were collected at the Aquarium of Boise. The Aquarium of Boise is a small, 501-C3 non-profit institution located in Boise, Idaho, USA. This venue was selected because of their regular live-animal presentations the public can attend (these occur in a small classroom, in which anywhere from 10 to 25 guests typically attend), and the willingness of the executive director to have the aquarium participate in this project. An evolution presentation was adapted to the format of a regularly occurring live animal presentation.

The methodology of this study employed a pre/post questionnaire using self-selecting sampling. Guests were recruited through social media posts by the aquarium, and announcements made at the aquarium. Participants were compensated with a cup of food to feed fish in one of the aquarium's exhibits upon return of the completed survey. These announcements advertised a free live-animal presentation that guests could attend and optionally fill out a survey for research purposes. The announcements differed from typical announcements by the aquarium regarding live animal presentations only by the inclusion of the potential benefit of free fish food. Data were collected on 29 November 2019, and intermittently between 22 December 2019 and 4 January 2020. All presentations were performed by the same individual. While data were not collected on survey return rate, the presenter of the shows, who also collected surveys, estimated the return rate to be just about 50%.

Sample population

The sample population of aquarium patrons, consisting of 64 individuals who fully completed the surveys, was of a diverse background. Demographic information, including religiosity (which is measured on a scale of 8 to 40) is summarised in Table 1.

Presentation protocol

To create a presentation that followed the aquarium's already established live-animal presentations, included practices shown to increase acceptance of evolution, and kept both children and parents engaged, the theme of the presentation was learning about how to be a biologist. This presentation used a constructivist approach (Whitman 1993) and included teaching about the nature of science, teaching the mechanisms of evolution and encouraging a reconciliation of evolution and religion, all of which the literature has shown to increase the acceptance of evolution among undergraduate college students (e.g., Lindsey et al. 2019).

Teaching the nature of science

As previously cited, emphasising the nature of science has been shown to lead to gains in acceptance of evolutionary theory. The presenter introduced the nature of science to the audience by explaining that they would need to know how science, and evolution in particular, worked in order to be a biologist. The presenter explained that the scientific process includes: Making a puzzling observation; Asking a causal question about the puzzling observation; Developing a hypothesis rooted in theory to answer the causal question (this included a brief discussion about what scientific theories are, in which evolutionary theory was introduced in more detail to the audience); Developing an experiment to test the hypothesis; Coming to conclusions based upon the experiment.

Teaching the facts of evolution

Although the literature is mixed on the efficacy of teaching the facts of evolution as a means of increasing evolution acceptance, it was nonetheless considered necessary to describe some of the mechanics of evolution, as it was necessary for participants to be able to later directly apply what they learned about the nature of science.

To teach the audience the facts of evolution, the presenter explained to the audience that in order to develop a hypothesis to answer questions in biology, they needed to know about the theory of evolution. The presenter explained that the important tenets of evolutionary theory include: 1. There are differences in

Table 2. Reconciliation quotes

Author	Quote
Francis Collins	"The God of the Bible is also the God of the genome. God can be found in the cathedral or in the laboratory."
Albert Einstein	"Religion without science is blind… science without religion is lame."
Theodosius Dobzhansky	"Nothing in biology makes sense except in the light of evolution."
Pope Francis	"Evolution in nature is not inconsistent with the notion of creation."

Table 3. Measure of participant religiosity

Rate each of the following eight questions on a scale of 1-5. 1 meaning you strongly disagree, and 5 meaning you strongly agree:
My personal religious beliefs are very important to me.
My religion or faith is an important part of my identity.
If someone wanted to understand who I am as a person, my religion or faith would be very important in that.
I attend religious services regularly.
I practice the requirements of my religion or faith.
I believe in God
I consider myself a religious person.
I consider myself a spiritual person.

a population; 2. These differences are heritable; 3. Not everybody can survive and reproduce; 4.Those with the best traits survive and have offspring with the same traits they do.

An example was given of a population of fish that were colored either red or black. The audience was able to come to the conclusion that black fish would have black babies, and red fish would have red babies (postulates 1 and 2). A hypothetical situation was given to the audience in which a shark, that had a preference for eating red fish, came across the fish population. The audience was asked what would happen to the red fish, and they always concluded that the red fish would be eaten, and not be able to have babies, so the fish population would eventually all be black (postulates 3 and 4). The presenter explained that this is an example of a population evolving.

Audience application of the nature of science and the facts of evolution

The audience was then given an opportunity to apply what they learned about the nature of science and the facts of evolution. The presenter introduced the audience to a reptile. This was typically a European glass lizard *Pseudopus apodus* (also known as a sheltopusik or colloquially as a legless lizard). However, it could not be used for every presentation if it had just eaten, or was becoming restless, in which case a green iguana *Iguana iguana*, or ball python *Python regius*, was used instead. After each member of the audience was able to see the animal up close, the audience collectively came up with (1) A puzzling observation about the animal (i.e. "it doesn't have legs", "it has a long tail", "it has spots near its snout", etc.) and an accompanying causal question, (2) a hypothesis, rooted in evolutionary theory, that answered the causal question, and (3) a hypothetical experiment that could test whether the hypothesis is a correct explanation of how the puzzling trait helps the animal survive and reproduce. The presenter then shared the correct reason for why the animal has the trait and explained how the trait could have evolved.

The presenter then explained that since biology is the study of life, and humans are living, biology can answer questions about humans. The audience was then given a puzzling observation about humans (a map showing how the percent of the human population that can drink milk varies by part of the world) and asked the audience to give a hypothesis explaining why this phenomenon exists. The presenter prompted the audience to hypothesise that this distribution correlates to where cows evolved, and explained that those near cows who were able to drink milk were better able to survive to have offspring that were also able to drink milk (see Gerbault et al. 2011 for a further explanation of this phenomenon).

Reconciling evolution and religion

To help the audience reconcile religious beliefs with evolution, the presenter then explained that they recognised that evolution, especially in regard to humans, is likely a sensitive subject for some in the audience. They emphasised that it was not the intention of the presentation to offend those of religious faith. The presenter then explained that science answers questions such as "how did something happen?" or "when did something happen?", while religion answers questions such as "why did something happen?", "who/what, if anyone, caused this to happen?", and "for what purpose did this happen?" Because the literature has shown that giving college students a role model who accepts evolution and is religious is an important part of helping students reconcile evolution with their faith (Barnes and Brownell 2017; Holt et al. 2018), the presenter shared several quotes from religious and scientific figures showing support for evolution, or the idea of accepting both science and religion (Table 2) to finish the presentation.

Questionnaire design

Prior to the presentation, aquarium guests who were willing to participate in the study began filling out the survey. This survey could be filled out in paper form, or via a QR code participants could scan. Only six participants (7.69%) chose to use the QR code. As most participants had children with them who were eager to return to viewing animals at the aquarium, both brevity and accuracy were given high consideration when developing the instrument.

Religiosity

To measure if highly religious individuals were changing toward a more positive view of evolution, despite the barrier religiosity poses to evolution acceptance (Heddy and Nadelson 2013; Jensen et al. 2019) the study measured participant religiosity. Religiosity was measured using an eight-question, five-point Likert scale (Table 3), developed by Cohen et al. (2008), and modified by Barnes and Brownell (2017a), that has been validated for measuring religiosity in college students (see Barnes and Brownell 2017a for validation

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Table 4. Demographic measures

What religious denomination are you affiliated with (if any)?
Please circle your political affiliation:
Republican / Democrat / Independant / Other (Please state)
Please list your age:
What is the highest level of education you have completed?

of this survey). The range of the scale is from 8 (an answer of 1 for each item) to 40 (an answer of 5 for each item). This scale was filled out immediately prior to the presentation.

Demographics

To determine what type of individuals already had a positive view of evolution, or what type of individuals were inclined to change toward a more positive view of evolution, respondents were asked about their religious denomination, political affiliation, age and educational attainment (Table 4). These answers were used in conjunction with religiosity scores for statistical analysis. Participants answered these questions before the presentation began.

View of evolution

To measure participants' view of evolution, and how the presentation was affecting it, a modified version of the 100-point instrument of self-defined acceptance was used (Barnes et al. 2019). This scale uses a 100-point slider scale to answer the questions (1) "To what extent do you accept evolution?" (2) "To what extent do you believe evolution?" and (3) "To what extent do you think evolution is true?" (Barnes et al. 2019). Because of the redundancy of questions 2 and 3, the third question was changed to ask about participant openness to evolution, as it was felt it would capture a broader portion of participant view of evolutionary theory. The wording of the first two questions were altered slightly (Table 5) and evolution was broken down into categories of (1) adaptation (2) speciation and (3) human evolution to determine where the change was occurring in participants' view of evolution (if it changed at all).

Subjects filled out this portion of the instrument both before and after the presentation by simply picking a number between 0 and 100 to put in each of the boxes indicating the percentage to which they accept the statement.

Statistical analysis

Survey analysis

In addition to the answers to each individual question of the modified version of the 100-point scale of self-defined acceptance (Table 5), total acceptance, total belief and total openness scores were calculated for each individual from the sum of the adaptation, speciation and human evolution score for each category (max 300). A total score was calculated from the sum of all of the answers (max 900) for all 64 participants.

Pre-predictors

To determine who in the audience was already accepting of evolution, and to see how it compared to those who would potentially change toward a more positive view, a multiple regression analysis was carried out using religiosity, religious denomination, political affiliation, age and educational attainment as predictors of a composite score for the total answer of the pre-evolution survey. A total of 64 complete responses were included in the analysis. One point had a high leverage value (lev=0.2556); however, it was well within three standard-deviations (sd=1.27630) and was thus included in the analysis. Religiosity and age were included as linear variables in the model, while all other predictors were included as categorical variables.

Predictors of change

To see who was most likely to change in their view of evolutionary theory, a multiple regression analysis was carried out of the 48 individuals who did not have the maximum composite score of 900 (21 respondents had a perfect score of 900 and were excluded). The analysis used religiosity, religious denomination, political affiliation, age, level of education and total openness to evolution as predictors for the change from the pre-total to post-total score. One data point that was outside of 3 standard deviations (SD>8) was not included in the regression. Three points had high leverage (lev=0.28831, 0.24362 (2)), but were all within 1.1 standard deviations, and were still included in the multiple regression. Overall, 47 data points were used for this regression.

Table 5. Modified Version of the 100-point instrument of self-defined acceptance

	Over time, a species can adapt to better survive in its environment.	New species can evolve over time.	Humans evolved from primitive life forms.
To what extent do you accept each of the following statements?			
To what extent do you believe each of the following statements are true?			
To what extent are you open to each of the following statements?			

Table 7. Summary of Sign Tests

	Pre-median	Post-median	Positive change	Negative change	No change	Significance
Accept adaptation	100.00	100.00	12	0.00	36	<0.001*
Accept speciation	80.00	95.50	14	2	32	0.004*
Accept human evolution	20.00	20.00	9	0	39	0.004*
Total acceptance	198.00	200.00	19	2	27	<0.001*
Believe in adaptation	100.00	100.00	12	3	33	0.035*
Belief in speciation	80.00	85.00	12	2	34	0.013*
Belief in human evolution	2.50	15.00	7	0	41	0.016*
Total belief	200.00	200.00	17	4	27	0.007*
Open to adaptation	100.00	100.00	5	1	42	0.219
Open to speciation	100.00	100.00	7	1	40	0.070
Open to human evolution	20.00	25.00	5	1	42	0.219
Open total	202.50	215.00	8	2	38	0.109
Total change	600.00	610.00	20	3	25	<0.001*

Measuring change from pre to post

Pre- and post-scores were compared to determine the change in participants' view of evolution. Because the data did not meet the assumption of normality (all Shapiro-Wilk statistics <0.05), a non-parametric approach was used. The sign test was used, which determines the probability that the difference between median values is equal to zero, thereby signaling if the number of individuals who changed was significant. For the individuals who did not have a pre-score of 900 (n=48), pre- and post-scores were compared for each individual question (i.e., accept adaption, open to human evolution, etc.), total acceptance, total belief and total openness. The participants who had a pre-score of 900 were not included in this analysis because none of their scores shifted. All analyses were performed in SPSS.

Results

Predictors of initial view of evolution

Results of the linear regression show a collective, significant effect of all factors included in the model [$F(5,63)=4.874$, $P<0.001$, $R^2=0.296$]. No individual factor was significant on its own.

Predictors for change in view of evolution

The model for predicting change in the total score amongst those who did not already fully accept evolution was unable to explain any of the variance seen ($R^2=0.110$, adjusted $R^2=-0.052$, $P=0.668$). Of the individual predictors tested (religiosity, religious denomination, political affiliation, age, educational attainment and pre-openness), none was a significant predictor of change.

Changes from pre to post

Sign tests comparing pre- and post-scores indicated significant differences in all categories of acceptance, including total acceptance, all categories of belief, including total belief, and overall view of evolution (Table 6). However, there were no significant changes in openness toward evolution in any of the categories.

Discussion

Change in view of evolution

The results indicated a positive shift in attitude towards evolution, with the exception of openness. These results are in alignment with several studies that have shown large changes in the acceptance of evolution, or a reduction in perceived conflict towards evolution, amongst undergraduate students using approaches similar to those we used (Manwaring et al. 2015; Barnes and Brownell 2017; Barnes et al. 2018; Lindsay et al. 2019). The results also confirm prior work showing that public opinion can be changed in a short amount of time at zoos and aquariums (Moss et al. 2015; Jensen et al. 2017; Moss and Pavitt 2019). These results are novel, because there has been little research showing that public opinion of the theory of evolution can be shifted outside of the arena of formal schooling, and, to the authors' knowledge, Barnes et al. (2018) are the only authors to have looked at change in view of evolution through a brief intervention. Additionally, results show that zoos and aquariums are viable venues for change in public perception of evolution, and that practices shown to be effective in universities can also be effective in a public setting. Findings by Jensen et al. (2017), which showed that after two years, zoo patrons retained "improved knowledge of actions to help protect biodiversity", gives reason to believe that the change we found could be lasting. Additional long-term research should be done to determine the longevity of this shift in opinion.

Predictors of change

In determining what factors were predictors of initial view of evolution, the model was significant ($P<0.001$), but no factor was significant on its own. Importantly, the model was not predictive of individuals who were shifting to a more accepting view of

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evolution. It is incredibly important that there were no predictors of change. Research has shown that political affiliation (Pew 2013; Funk 2014; Nadelson and Hardy 2015), religious denomination (Pew 2013; Barone et al. 2014; Jensen et al. 2019), age (Pew 2013; 2015), religiosity (Heddy and Nadelson 2012; 2013; Barone et al. 2014; Jensen et al. 2019) and education (Heddy and Nadelson 2013; Pew 2013; 2015) all influence acceptance of evolution. It is promising that none of these demographics correlated with a propensity to change. The present results indicate that there were no certain demographics that dampened change toward a more positive view of evolution.

Limitations

It is conceded that, given the small sample size, caution must be taken when interpreting the present results. Specifically, the sample for linear regression falls shy of some recommended requirements as described by Tabachnick et al. (2001). Another consideration is that by compensating participants with fish food, it is possible that individuals inherently more interested in biology and thus more accepting of evolutionary theory were selected. That being said, significant or noticeable upward trends in acceptance of evolutionary theory were observed, even given the small and non-invasive intervention. Additional work is required by larger institutions with access to a larger sample size.

Conclusion

The effectiveness of using brief versions of teaching practices validated in college classrooms to change public opinion about the controversial topic of evolution is very encouraging. As Dobzhansky (1973) famously observed, "Nothing in Biology makes sense except in the light of evolution" (p.125). Because of how integral evolution is to all facets of biology, public understanding and acceptance of evolutionary theory is crucial to address urgent crises such as vaccination hesitancy, misuse of antibiotics leading to resistant bacteria, an unprecedented loss of biodiversity, and global pandemics such as COVID-19. Indeed, research has shown that students who understand, but do not accept, evolutionary theory are not likely to apply evolutionary thinking when they are making public decisions related to biology (Sinatra et al 2003; Rosengren et al 2012). Because of public exposure to zoos and aquariums, AZA affiliated institutions host 183 million annual visitors in the US alone (Visitor Demographics 2011), and worldwide attendance at zoos and aquariums has been estimated to be 700 million annually (Gusset and Dick 2011). The present results suggest that zoos and aquariums could potentially have a large impact on public perception of evolutionary theory. The present success with strategies shown to be impactful in formal educational settings also implies that if zoos and aquariums use approaches validated in education literature, they could have success educating the public about other controversial scientific topics such as climate change and vaccines. Zoos and aquariums across the world are called upon to educate the public about such seemingly controversial topics, using approaches shown to be effective in formal education settings, as the present results suggest this approach could have profound societal impacts.

Conflict of interest

The authors had no conflicts of interest with this study.

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