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Tips & Tools

Development of Oral Communication Skills by Undergraduates that Convey Evolutionary Concepts to the Public †

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INTRODUCTION

Scientists have a responsibility to promote democracy and communicate scientific information to the general public (1, 2). Unfortunately, a disconnect exists between the scientific community's and the public's definition of good science (2). To the scientific community, "good science" is exemplified by responsible conduct of research (e.g., ethical treatment of subjects, addressing research misconduct, and proper data management). Yet to the public, "good science" is conducting research that has broader (positive) societal impacts, as well as communicating those implications to the public. In an age of numerous communication outlets (e.g., blogs, television, radio, and social media) it would appear this task of communicating scientific information to the public would be straightforward. However, scientists note that communicating ideas to the general public can be both difficult and dangerous, the latter because the public may misunderstand them (3).

Historically, communication efforts were built upon the "deficit model," that is, the idea that the public's mistrust of or non-belief in science was rooted in individuals' lack of knowledge (4, 5). However, the data paints a different picture. Individuals' scientific knowledge is only weakly related to their attitudes toward science (4). The literature indicates that evidence alone does not change beliefs; framing (5), engaging in two-way dialogue (5), and serendipitous encounters (6) provide effective avenues for informing and engaging the public in scientific endeavors (5).

Possessing the skills to communicate scientific information requires practice. However, traditional scientific training (i.e., receiving an undergraduate science degree) and assessments have focused on building students' content knowledge, knowledge of terminology, and ability to communicate with other scientists. As a result, the majority of undergraduate biology programs do not include a focus on building their students' ability to communicate scientific-related information to nonscientists (7). As science permeates multiple areas of all individuals' lives, trained scientists have a responsibility to provide the public with scientific information (7–9). Therefore, we concur with the American Association for the Advancement of Science that it is imperative for students graduating with an undergraduate biology degree to receive instruction, practice, and assessments in broader communicative abilities (1).

Using the topic of evolution as a platform, we have created a series of activities designed to provide students the opportunity to develop their ability to *speak* with nonscientists about evolution. These activities align with educational researchers' (7) suggestions 1) to integrate the teaching of communication skills with the building of content knowledge, 2) to provide students with multiple opportunities to develop their communication skills, and 3) to use authentic activities.

PROCEDURE

In this Tips and Tools article we present three activities: 1) an in-class formative assessment, 2) an in-class practice activity, and 3) an out-of-class summative assessment.

Activity 1: Formatively assessing students' evolutionary knowledge

The first activity requires 45 to 50 minutes to complete and is composed of small group discussion followed by instructor feedback and direct instruction. We recommend this activity be completed before the students have had formal instruction related to evolution.

1. Form student groups (three or four students per group).
2. Student discussion. Students are given a set of nine evolutionary related statements (Table 1), previously cut into strips and placed in an envelope. Students randomly pull out a statement and, as a group, discuss whether they agree or disagree with the statement. We recommend giving the students 15 to 20 minutes to discuss the statements.

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TABLE 1.
Statements for first day's activity.

Statement	Follow-Up Discussion Questions and Starters
1. Evolution is a theory about the origin of life.	• What is the scientific versus lay definition of theory? • Evolution does provide evidence for possible origins of life, but a larger portion of evolution focuses on how the diversity of life forms on earth developed.
2. Evolution is striving toward higher forms of life on earth.	• Evolution is not goal orientated. Nature cannot make choices.
3. Because evolution is slow, humans cannot influence it.	• In what ways have humans influenced evolution? In medicine? In agriculture? In domestication?
4. Individual organisms adapt and change to fit their environment.	• There are at least two problematic issues with this statement.What are they? • What is the scientific versus lay definition of adapt? • Evolution works at the population, not individual, level.
5. Humans are currently evolving.	• Do you know of any examples of human evolution? • Share examples of human evolution (e.g. increased abundance of sickle-cell anemia in populations with a high-risk of Malaria).
6. Evolution is a result of random events.	• What types of random events can cause evolution? • What types of non-random events can lead to evolution?
7. Evolution can occur quickly.	• What types of events would cause evolution to occur quickly? • Provide students with a hypothetical situation and have them predict how various events could lead to rapid evolution. (For example, a hurricane destroys the majority of a population of birds; the remaining population has a low level of diversity. How would future generations of the birds compare with previous generations?)
8. Genetic drift does not occur in large populations.	• Define genetic drift. • How would the effect of genetic drift influence small populations compared with large populations?

Statements were modified from the University of California-Berkley's *Understanding Evolution: Misconceptions about evolution* website: http://evolution.berkeley.edu/evolibrary/misconceptions_faq.php. Some of the misconceptions were restructured to represent accurate biological statements, whereas others were left in their original form.

3. Instructor-led discussion. For the remaining class period, the instructor can use the statements to discuss common misconceptions related to evolution and problematic terminology (i.e., terms that are used differently by lay individuals compared with how the scientific community uses them, such as *theory* and *adapt*). Depending on the size of the class, an instructor can simply ask students to raise their hands and identify which statements they thought were biologically incorrect and why. In a larger class, the instructor may use personal-response systems (e.g., clickers) to receive feedback from the students. We provide example discussion questions in Table 1, but teachers of evolution can generate additional questions for discussion.

Activity 2: Practicing communicating

For the remainder of the semester, at the end of each unit, students participate in an activity similar to Activity 1. Students are once again placed in small groups and given common misconceptions to discuss. However, the students are now equipped with knowledge to combat the statements given. Students are encouraged to role play, taking turns serving as a lay individual with a misconception and a scientist. Students are to practice confronting misconceptions and using nonscientific language to promote the lay individual's understanding of evolution as well as to help that person link evolutionary information to their life. Students are encouraged to give one another feedback.

Activity 3: Summative and authentic assessment

As a cumulating activity, students are asked to interview a nonscientist (e.g., family member or friend) in relation to their evolutionarily-related opinions (Appendix 1). The interview is a reiteration of the in-class activities. After the students have explained the project to their interviewee, they are to ask the interviewee about whether or not they agree with various evolutionary misconceptions. Students should be instructed that the goal is not to be confrontational but to build a relationship of trust and encourage dialogue

with their interviewee. Students whose interviewees do not accept the theory of evolution are encouraged to use questioning strategies to try to reveal misconceptions and provide the interviewee with concrete examples to refine their thinking. However, once again, the goal is to have an open, nonconfrontational dialogue. For students who interview individuals who agree with the theory of evolution, they are encouraged to still probe for the individual's understanding. We chose to grade this assignment on completion; student turned in an audio-recording of their conversations. (Audio data were reviewed for research purposes in accordance with the University of Northern Colorado, Institutional Review Board, policy, exempt level, internal reference number 893844.) For instructors wishing to use more formalized grading procedures, we recommend having students review their interview and write a reflective paper on the difficulties of communicating scientific information with nonscientists and how they could have improved their conversation or participating in peer-feedback. In the peer-feedback model, students can evaluate one another's interviews and provide feedback on how to improve their communication.

CONCLUSION

Science permeates everyone's lives, scientists and nonscientists alike (e.g., climate change and medical decisions). Despite the deep connection between science and everyday life, research indicates that the majority of the US population lacks the basic scientific literacy to read the Science section of the *New York Times* (10). Compared with the general public, students receiving their degree in biology are scientific experts. As undergraduate biology educators, we need to equip these experts with the skills needed to communicate scientific information with their nonscientific peers. By transcribing students' cumulative assignments, we were able to qualitatively identify that although students did not identify and/or choose to confront all their interviewees' (i.e., the public's) misconceptions, students demonstrated the ability to 1) use questioning techniques to help reveal and reconstruct interviewee's misconceptions, 2) use concrete examples to refute a misconception and explain a biological phenomenon, and 3) clarify lay individuals' misunderstanding of evolutionary terminology (Table 2). Furthermore, transcripts indicated that the majority of students used a nonconfrontational approach, encouraging an open dialogue with the public—an important factor in communicating scientific information to the public (11). Although not directly assessed (i.e., we did not measure changes in interviewees' understanding), these "serendipitous" conversations provided students the chance to develop the public's appreciation and understanding of the nature of science. In more than one instance, the students could describe to the public how scientists collect data to support the evolutionary theory. Yoho and Vamali (12) emphasize that key factors in effectively communicating with lay individuals is to build individuals' understanding of the value of science and the nature of science. By providing interviewees with information on how data were collected and how theories develop, the students may have assisted in developing interviewees' understanding of the nature of science.

Conflicts with lay terminology and ideologies can make discussing evolution with nonscientists a daunting task. We provided a model that allows instructors to identify students' evolutionary misconceptions (Activity 1), to provide students multiple opportunities to practice oral communication (Activity 2), and to assess student skills with an authentic summative assessment (Activity 3). These activities promote student learning, by providing the learner with the opportunity to deeply engage with material. Furthermore, we believe that when students are provided the opportunity to learn by practicing conveying scientific concepts to the public, they develop a deeper understanding of the content.

SUPPLEMENTAL MATERIALS

Appendix 1: Communicating science with nonscientists assignment

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We would like to thank Mario Trujilo and Anjel Vasquez for their assistance in transcribing students' cumulating activity. The authors associated with this work, Lacy M. Cleveland and Robert J. Reinsvold, piloted the described learning strategy in a small class (*n*=24) in the summer of 2016. In the spring 2017 semester, the authors will begin a multiple-year, longitudinal study comparing this technique with other techniques on students' short-term and long-term learning gains, attitudes, and communication skills. The authors plan to publish the longitudinal impacts in future years.

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TABLE 2.
Qualitative examples of students' ability to correct the public's misconceptions about evolution.[a]

Method for Correcting Misconception	Representative Quote
1. Using Socratic questioning	Interviewee: I was born, I mean I was taught ever since I was younger that is, we're not from evolution so it's one of those things that is ingrained in me. Student: Okay, so like the fossils do they, do you think they prove or disprove evolution or like…? Interviewee: I think that they are interesting and that they, the fossils for what we believe is that they came from the great flood. So that the dinosaurs were one of the animals that were wiped out during the flood. So that's where we think the fossils come from. Student: Alright, so with that, there being fossils found a lot earlier that pre-date dinosaurs how do you explain those?[b]
2. Supplying concrete examples	After interviewee expresses that (s)he does not know how an individual could test or observe evolution the student responded: "Yeah, like one example could be the fossil record. Through the fossil record we were able to see how organisms evolve through time or how the organisms that were in that time, like what were the features of the organisms during a period of time and what are the features of the organisms of, now. Like we can compare and contrast. So, and that would be observable because you're observing how a certain organism changed over time through the fossil record and that's how we were able to know how organisms lived during that time period."
3. Clarifying incorrect terminology	Student's response to an individual's misuse of the word theory: "Well that's actually a common misconception about evolution. Yes conversationally, when you say the word theory it implies more like, "Oh, I've had an idea." Or, "Hmm, maybe this could be a possible explanation." But when you're talking about the scientific fields, the word theory is actually far more confirmed maybe, in that when you say theory it's more like a set of confirmed tested hypotheses that all have the same conclusion. So it is not only an idea but it is confirmed on multiple different routes."

[a]All data were collected in accordance with the University of Northern Colorado's (UNC) Institutional Review Board approval, internal reference number 893844. UNC's Institutional Review Board deemed this project as exempt.

[b]The student went onto ask the interviewee about carbon dating. The interviewee made it clear that (s)he was a creationist. The student did an excellent job of describing how (s)he disagreed with the individual but asked the individual to share his/her thoughts on the Great Flood, building a relationship of trust and open dialogue. Both of these characteristics, building trust and promoting dialogue are considered key attributes for scientists wishing to communicate effectively with laypeople (11).

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