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Scientific Citizenship

Controversy in Biology Classrooms—Citizen Science Approaches to Evolution and Applications to Climate Change Discussions

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The biological sciences encompass topics considered controversial by the American public, such as evolution and climate change. We believe that the development of climate change education in the biology classroom is better informed by an understanding of the history of the teaching of evolution. A common goal for science educators should be to engender a greater respect for and appreciation of science among students while teaching specific content knowledge. Citizen science has emerged as a viable yet underdeveloped method for engaging students of all ages in key scientific issues that impact society through authentic data-driven scientific research. Where successful, citizen science may open avenues of communication and engagement with the scientific process that would otherwise be more difficult to achieve. Citizen science projects demonstrate versatility in education and the ability to test hypotheses by collecting large amounts of often publishable data. We find a great possibility for science education research in the incorporation of citizen science projects in curriculum, especially with respect to "hot topics" of socioscientific debate based on our review of the findings of other authors.

INTRODUCTION

The biological sciences include topics that are viewed as controversial and even antithetical to the beliefs of some members of the public. Thus, research into new teaching methods, strategies, and tools for controversial topics could strengthen the educational experience as well as offer an assessment of teaching outcomes with respect to both material mastery and general attitudes toward science. When presenting science to general audiences, the primary goals often are to develop a fundamental appreciation of science and the scientific process in addition to specific content knowledge (32, 34, 35). This appreciation of science can be developed through engaging students of all ages—from elementary to elderly—in explicit and reflective discussion and hands-on experiences, i.e., research (1, 33).

Among the topics perceived as controversial in the biological sciences, perhaps the most commonly discussed is evolution (4, 31, 55). In recent decades, the educational setbacks and gains from teaching evolution in the United States provide a needed frame of reference and offer insights into instructional methods (22) for other "hot" topics such as climate change, genetically modified organisms (GMOs), and cloning, among others. Teaching climate change content in a biology classroom is complicated by many factors, some of which are present also when teaching evolution. Biology instructors and researchers regularly encounter the interconnected nature of the environment and organisms; contemporary discussions of climate change therefore should be enriched by fundamental concepts such as evolution and extinction.

Citizen science, the practice of nonscientists collecting information for investigations in an organized manner that yields data to test hypotheses, represents a key method to link science education and environmental education (5, 6, 7, 12, 15, 48, 54). Additionally, it may create a foundation for enhancing the engagement of citizens of all ages with the sciences by allowing them to participate actively rather than passively in science. The expansion of inquiry-based

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education to encourage curiosity also has led to the rise of publishable research based on well-crafted testable hypotheses, with students participating in the faculty member's research project (25). Citizen-science projects in evolution have shown success in allowing ordinary citizens to help test important hypotheses, a notable example being the large-scale Evolution MegaLab project, which spanned 15 countries and involved over 6,000 participants (56). Other notable citizen-science examples include eBird and Zooniverse (6, 18, 50, 59). Additional projects cover a variety of areas, from ecology to comparative genomics (27, 46, 48). Recently, developments in smartphone use platforms (36) and social networking patterns (16) have multiplied the ways popular technologies can be integrated into citizen-science research. Mobile devices and social media may be useful tools for encouraging participation. However, regardless of these advances and expanding projects, the results of such research are not often accepted as traditionally publishable data in the peer review process, but instead as education or outreach only (7). New interest from scientific and educational research perspectives must be utilized to validate the data generated and develop an appreciation for the scientific process.

DISCUSSION

American instructors in the earth and space sciences who cover "controversial" topics in science must be aware of the potential for controversy and respond respectfully to engage students, parents, the community, and their peers (26). Although environmental concerns receive significant public and media attention, the public has a poor understanding of the science in general, especially as these topics often require drawing upon information from multiple disciplines (52). Several key parallels exist between evolution and climate change, scientifically and in terms of public perception. Beyond discussing extinction or evolution, the topics share many similarities in how they are presented to students. Citing the teaching of evolution, Hermann (23) calls upon several key concepts (noted in italics), which we can extrapolate for these purposes to the teaching and learning of climate change:

1. *The issue represents a socioscientific controversy, not a scientific controversy.* That 97% of climate scientists are convinced about the human-caused warming trends while more than one-third of Americans reject the evidence of average global temperature increases (39, 40) is an ideological issue in a country that values ideology strongly. Herein, we acknowledge the nature of the debate being limited to "controversial" in the public eye, which classifies it as a socioscientific debate, not a scientific one (57). The major distinction between climate change and evolution is the nature of the sides—evolution is disagreeable with certain religious groups and climate change finds opposition primarily in the political arena.
2. *Conceptual frameworks for both span multiple scientific* [and non-scientific] *disciplines.* The teaching of evolution relies on the conceptual understanding of several sub-disciplines. On a larger scale, climate change and its implications require an even greater diversity of knowledge of many fields to understand the vast effects, even outside of the traditional science disciplines, with far-reaching implications into our everyday lives (42).
3. *There is debate, disagreement, and uncertainty between opposing sides.* Primarily, we encounter the "sides" of this debate in the media and political arenas. In both situations, the press plays a key role in influencing public opinion to perpetuate these debates. Although outside of our primary focus, legislature and politics often complicate the interactions of civics and education. For example, several states (Louisiana, South Dakota, and Tennessee) have legislature-mandated laws concerning the teaching of climate change, including aspects such as teaching it as a controversy (26). Creating a circular argument, governmental policy is driven ideally by constituent opinion and may be a direct reflection of citizen opinions.
4. *A clear path or decision does not exist for a "reasonable member of society,"* with "reasonable" being defined in an ethical sense by Kupperman (29). Controversial topics in the biological sciences generate many perspectives and receive commentary from a variety of perceived authoritative sources. It is difficult for a lay audience to create informed, educated viewpoints, especially when an overabundance of information is available or the perceptions challenge personal beliefs or value systems (45). Beyond the quantity of information, creating an organizational structure for analyzing information can be difficult for the lay audience.

In the literature, a number of instructional methods exist for engaging students in both general and controversial science topics. With evolution, the instructor's approach can fit into one of four general categories: advocacy, affirmative neutrality, procedural neutrality, and avoidance (23). These include, respectively, arguing for a side, presenting several positions, allowing students to present sides from resources, and omitting the conversation (23). Regardless of the instructor's choices relative to the topic, the educational approaches for evolution span a representative distribution of methods, including a selection from the nature of science (11, 24, 34, 35, 37, 42, 55), geological time (11, 30), as well as questioning, case studies, and law (20, 38). Relatively understated in the literature are studies evaluating the efficacy of newer active learning methods such as citizen science with respect to controversial topics. Among those

present, selected examples generally include teaching tools for inquiry or active learning, for students (8, 9, 17), or teacher training (14).

In the classroom, for example, science educators often have found success in teaching controversial topics (e.g., evolution) to traditionally non-receptive audiences by developing an understanding of the nature of science (47) and the value of the scientific process. As science teaching continues to move toward many established and/or validated active learning methods in the classroom (21), we must engage students in new ways on key issues, especially those of socioscientific controversy (2). Issues-based teaching favors a science curriculum that politicizes students and promotes empowerment through civic participation, decision-making, and action (43, 44, 57). One method of engaging people in controversial topics is to use various forms of communication, such as conversations, argumentation (19, 28), cognitive conflict (45), and citizen/expert panel simulations (3, 10).

To expand on interactive student experiences, citizen science projects have the ability to engage students and the larger community alike. Social and ethical issues offer students opportunities "to attach personal meaning to science concepts, theories and processes, and enable investigations that are closer to students' daily existence" (58). This may enable educators to bring focus to important ideas by engaging students through emotional and intellectual stimulation, transforming otherwise distant topics into those central to their everyday lives (58). Although both evolution and climate change include some current citizen science projects, a continued expansion may be an educational opportunity for students of all ages, from the classroom to the community. These projects can expand on the use of inquiry in the classroom to create large-scale research projects. Additionally, students may gain a greater appreciation of science by being involved in areas of non-simulated research, as opposed to the traditional "cookbook" labs.

When considering the use of a citizen-science approach for climate awareness and education, a primary advantage is the past success demonstrated in citizen science. Several ongoing citizen science projects mentioned, including, for example, those of The Cornell Lab (13), have been shown to generate large amounts of scientifically valuable data while educating participants in the process of science and the specific areas of investigation (6). In North America alone, there may be more than 200 research projects (12), and several projects (notably eBird and Zooniverse) have led to scores of publications in many fields (7). Additionally, climate change project examples span a range from active participation in parks (41) to volunteering computer processing time (53). Although some of these projects have turned into published scholarly works, the field of citizen science as a whole is underdeveloped and seen as an educational opportunity (6). Additional opportunities exist to evaluate the educational aspects of these projects, as these remain understudied compared with other teaching techniques (51) such as those used in active learning or inquiry-based approaches.

Interestingly, studies focusing on the research and educational benefits of citizen-science projects for studying local and global impacts of climate change appear to be relatively underdeveloped in the literature. This represents an opportunity, especially for science education researchers. Beyond the possibilities of data generation and publications for the coordinating researchers and organizations, a key aspect of the citizen-science project is the education of nonscientists in how science works, as well as specific, project-related content (6, 51). Especially in those more controversial topics, public perception relies strongly on the overall perception of science. With citizen science, we can effect change through engagement to develop an appreciation for science in everyday life.

Using the principles of citizen science, students of all ages can be involved in research. Although ecology, evolution, and climate change are vastly interconnected, such studies have yet to show a strong presence in the science education literature. Searches of popular academic literature sites, for example Web of Science and ERIC Social Sciences database, with Boolean key words "citizen science AND education AND climate change" reveal approximately 50 or fewer total results, most of which relate to developing a productive or knowledgeable citizenry, instead of a citizen-science research project. The limited results show a large unexplored niche in educational research for the integration of citizen science in the curriculum and subsequent studies for efficacy or validation. In the case of climate change, this integration would be possible across many disciplines, especially with established topics of socioscientific controversy.

CONCLUSION

Many of the controversial topics in the biological sciences represent some of the most challenging concepts for communication and education in the sciences. The utilization of a variety of teaching tools to cover these subjects effectively and the continued investigation of new teaching methodologies for the education of students of all ages will be necessary to improve the appreciation for and understanding of subjects to which there is popular opposition. With citizen science in particular, there also exists an additional beneficial outcome: the ability to generate large-scale, publishable data for studies that may exceed traditional limitations. As both scientists and educational researchers, we can expand the opportunities for engaging nonscientists in research in the hope of strengthening the appreciation for and understanding of science in the general population, the "students" of any age. In turn, this positive experience may create excitement for scientific topics and empathy for the preservation of our only habitat.

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