Considering Grand Challenges in Undergraduate General Biology Education: Integration, Big History, and Scientific Literacy

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Abstract Higher education finds itself at a crossroads in regard to providing students of all majors with curricula that addresses a higher level of critical thinking skills along with evidenced based decision making. Within the walls of academia, educators and administrators alike are facing grand challenges in developing biology programs, which encapsulate the complex and interconnectedness of the biological sciences, while at the same time embedding the scientific literacy skills found within the field of biology. Here I argue for the integration of Big History content within general biology education courses.

Integration

Albert Einstein once said, “all religions, arts, and sciences are branches from the same tree” (Einstein 2006, 7). Einstein’s view holds that a broad and interdisciplinary education is essential to the preparation of citizens for life, work, and civic participation. An interdisciplinary approach to general biology education weaves together the discoveries of the evolutionary sciences together with humanities, such as history, philosophy, literature and art. Our world is complex and interconnected; it is no surprise that biology and the history of life is, too. An educated and scientifically literate mind empowers students to separate scientific truth from falsehood and pseudoscience and bias from fact (NAS 2018).

In 2018, the U.S. National Academies of Sciences, Engineering, and Medicine published a report entitled *The Integration of the Humanities and Arts with Sciences, Engineering, and Medicine in Higher Education: Branches from the Same Tree*, in which they stated, “[g] iven that today’s challenges and opportunities are at once technical and human, addressing them calls for the full range of human knowledge and creativity. Future professionals and citizens need to see when specialized approaches are valuable and when they are limiting, find synergies at the intersections between diverse fields, create and communicate novel solutions, and empathize with the experiences of others” (NAS 2018, 8). Furthermore, the aforementioned report highlights the current and future challenges students will face in their respective professions, (i.e., the enormous strides in technology, including artificial intelligence, machine learning, robotics, and communications). Graduates will need to be able to adapt and continuously learn alongside these new technologies. The report goes on to say that “each person entering the job market today will look forward not only to several jobs, but also several careers, during her working life. All these factors have led to the expectation that current generations entering the workforce may, for the first time in recent American history, face a more uncertain future than their parents’ generation.”

It is no secret that current day humans rely more on science and technology than ever before. One can argue that in this manner, we have reached a new threshold in our lives on this planet. As such, humans are living in an increasingly scientific world. Science can be found all around us and that a more integrative approach to higher education will better serve effectively to prepare students for work, life, and citizenship in the Anthropocene Epoch: the current geological epoch caused by spectacular changes on Earth due to increasing globalization, changes in the chemistry of our atmosphere and oceans due to increased levels of human energy used in the form of fossil fuels, the exponential increase in human numbers, human control over the environment, and the ever increasing reliance on non-sustainable natural resources. "We take scientific principles for granted every time we use a piece of technological apparatus, such as a car, a computer, or a cellphone. In today's world, citizens frequently have to make decisions that require them to have some basic scientific knowledge. To be a contributing citizen in a modern democracy, a person needs to understand the general principles of science" (Oliveira 2008, 24).

"Historically and traditionally in the United States, broad study in an array of different disciplines—including the arts, humanities, sciences, and mathematics—as well as in-depth study within a special area of interest, has been a defining characteristic of higher education. Over time, the curriculum at many colleges and universities has become focused and fragmented along disciplinary lines. This change in higher education has been driven, in part, by increasing specialization in the academic disciplines and the associated cultural and administrative structure of modern colleges and universities" (NAS 2018, 1).

The obvious question facing higher education faculty and administrators then becomes whether an education focused on a single discipline best prepares graduates for the challenges and opportunities presented by work, life, and citizenship in the twenty-first century, or whether an approach to education that intentionally integrates knowledge in the arts, humanities, physical and life sciences, social sciences, engineering, technology, mathematics, and the biomedical disciplines, be more effective and applicable to various professions?

The curriculum should help students understand the connections among the disciplines and emphasize the point made by Einstein that all disciplines and forms of inquiry are "branches from the same tree." Extending this idea further, integration of content should emphasize human knowledge as fundamentally connected. Overall general education courses should be taught as a "network of branches arising from a trunk made up of human curiosity, passion, and drive, but also generative, as new branches split off and grow from old branches, extending into new spaces or coming in contact with other branches in new ways" (NAS 2018). In order to address these grand challenges, leaders and scholars in higher education and industry with expertise in the arts, humanities, social sciences, natural sciences, engineering, and medicine—and the intersections among these disciplines—should "sit at the same table" and develop course curricula that better represent the diversity and challenges current and future students will face in American higher education, in their future professions, and as scientifically literate citizens.

Scientific Literacy

Another grand challenge in this scientific world, however, is that most people are not scientists; nor should they be, since the human story should not start and end in science. As a result, most of the people in our world are not as scientifically literate as we would like them to be in order to understand the world and universe of which they are a part. These people, who comprise the majority of the population, have great power in the world, and some are involved in decision-making professions (i.e., politicians, businessmen, judges, CEOs, etc.). These are the ones who decide the funding and policy of scientific research. This segment of the population might be called "non-science majors" (Oliveira 2008).

So what are the "grand challenges" in science literacy? According to the American Association for the Advancement of Science (AAAS), which is the world's largest general scientific society, current students of science and non-science alike need new skills, including the ability to think and contribute outside their disciplinary boundaries. Current and future science and non-science majors must become well versed at making connections among seemingly disparate pieces of information, concepts, and questions, as well as be able to understand and evaluate the data and evidence, presented. Furthermore, they must possess enough knowledge about related disciplines (e.g., chemistry, geology, physics, computer science, engineering, and the social sciences) to bring the requisite expertise to address complex issues such as global climate change and biodiversity loss (AAAS 2011). Another one of the grand challenges in science education has been the integration of science content with science process skills. Students need content, but they also require practice in the nature of scientific thinking and process and even opportunities to change preexisting attitudes and misconceptions. They need the practice in thinking critically while exploring ways to contribute outside disciplinary boundaries. It is, therefore, in the interest and benefit of society that non-science majors comprehend the basics of science methodology in order to make evidenced-based decisions. Unfortunately, most people do not have the most basic scientific notions and do not understand the methodology and processes of science.

Recent polling data indicate that just over 50% of Americans believe in special creation and of those polled about 40% believe that humans lived during the same time as dinosaurs (Gallup 2019). It is obvious that there is a serious disconnect between science content and scientific literacy among the public. At a time of critical scientific and human challenges such as climate change, nuclear proliferation, human overpopulation, massive habitat destruction and the loss of biodiversity, along with constant misinformation in the mass and social media, such as alien encounters and chemtrails, and disinformation on social media, a general education curriculum that embeds scientific and information literacy skills provides a much needed counteractive and reason to hope for the future.

Big History—Its Questions

- Where did everything come from?
- How did humans get to where they are now?
- Where do humans fit into the narrative of the cosmos and the history of our solar system?
- Where are humans and other living beings on our planet headed in the near and distant future?

The aforementioned questions have been asked and addressed by a multitude of origin stories and by various disciplines in academia. As a result, there has been an increasing specialization in the academic disciplines and the associated cultural and administrative structure of modern colleges and universities in order to address these questions as well. Recent scholarship and research in the field of big history have been asking whether higher education has moved too far from its integrative tradition toward an approach heavily rooted in disciplinary "silos." Various scholars and academics in the field of big history see these silos as representing an artificial separation of academic disciplines.

> All human institutions, professions, programs, and activities must now be judged primarily by the extent to which they inhibit, ignore, or foster a mutually enhancing human-Earth relationship. (Thomas Berry, quoted in O'Sullivan 1999, 43).

The content and information found within big history addresses the aforementioned questions as a single, scientific narrative, aligned with data-based evidence. For the first time in our shared human history, a human origin story grounded in science and "nourished" by the humanities exists. Big history explores cosmic evolution as a physically self-organizing process based on connection, interdependence, and the resulting emergence of life. In doing so, big history examines a range of interactions in the various thresholds of the formation of stars and galaxies, Earth, life, and human communities. It investigates ways in which we understand chemical and biological evolutionary processes and the implications for humans and our ecological future within the context of the Anthropocene. Furthermore, big history allows the learner to integrate the best available content from various disciplines, such as astronomy, physics, chemistry, biology, history, archaeology, and the arts, in order to understand better our common origin story with the hope of fostering a mutually enhancing human-Earth relationship.

"Big History seeks to understand the integrated history of the Cosmos, Earth, Life, and Humanity, using the best available empirical evidence and scholarly methods." (https://bighistory.org) The integration of big history content and process skills allows students the opportunity to

- Utilize scientific questioning skills, which are actively developed through in-class and out-of-class problem solving.
- Incorporate scientific terms and vocabulary with each other in class or in online discussion posts.
- Preview, review, study and assess their own learning.

Biology—Its Questions

In order to address the grand challenges involved in undergraduate general biology education, one must begin with highlighting the overall questions involved in the study of biology:

- What is this work we call biology?
- How should educators tell the story of life?
- What are the major milestones in biological discovery that expanded our knowledge of life on Earth?
- What role, if any, should the grand narrative of the formation of the universe and complexity play in biology education?
- What does it mean to be human?

The study of biology is usually defined as the study of the origin, evolution, and distribution of life on Earth. As such, the fields of big history and the biological sciences are both inherently interdisciplinary and are aligned well to promote a worldview infused by cosmic and evolutionary perspectives (Crawford 2019). It is well understood that most non-science majors are required to take at least one general education course in the sciences. Most students end up taking a general biology course, usually during their final academic year due to a fear and dislike toward the sciences. Unfortunately, most of the general education biology courses include a long and detailed survey of life on Earth along with a checklist of facts from which students are expected to master and understand without the larger context of *their* place in the universe and their kinship with all life on Earth, past and present. This results in the fragmentation of knowledge and learning.

The grand challenges that face faculty in the biological science in the development and implementation of collegiate-level undergraduate general biology courses include the development of an interdisciplinary understanding of the history of life on Earth, while integrating scientific inquiry and process skills within students. The fragmentation of knowledge and learning has been the historical norm. I argue that future general biology courses should depart from that past. The integration of big history with biology content lends itself well by examining a range of dynamic interactions in the unfolding of galaxies, Earth, life, and human communities. It allows students to investigate ways in which we understand evolutionary processes and the implications for humans and our ecological future. Students need content, but they also require skills and even opportunities to change preexisting attitudes. They need the practice in thinking critically while exploring ways to contribute outside disciplinary boundaries. Clearly, future citizens—biologists and non-biologists alike—must become adept at making connections among seemingly disparate pieces of information, transdisciplinary concepts, and questions, as well as be able to understand and evaluate evidence.

Conclusion

Following in the footsteps of Carl Sagan, Fred Spier, David Christian, Brian Swimme and Thomas Berry, the teaching and communication of biology needs to relate more with the general population; it needs to be relatable, engaging and awe inspiring in order to create an inherent motivation among students of science and non-science alike, and to be multi-disciplinary. The integration of big history and biology can and should serve as the answer to all this! The story of the evolution of life on Earth and our common human origins should be examined and discussed as a single, epic narrative, rather than a presentation of a series of facts separated by scientific knowledge and the humanities. This changes our perception so that we begin to see ourselves as an integral and critical part of this narrative (Swimme and Tucker 2011). The integration of big history and biology allows the learners to place themselves within the context of this modern origin story and, in doing so, students can better appreciate the complexity and awe of biological processes such as the self-organizing dynamics of the universe, natural selection, the transformation of matter and energy, the emergence of life, symbiosis, and co-evolution. As learners discover these intricate processes of cosmic and biological evolution, they better appreciate and awaken to the biology of wonder and complexity of our natural environment at this critical juncture in our planetary history and current place on Earth. This will allow scientifically literate citizens from all disciplinary majors and professions to foster a mutually enhancing human-Earth relationship as we continue to move forward in space and time and as the climate on Earth continues to change during the Anthropocene.

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