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Genetic Science Confounds Students

Feedback Tells Us What We Are Not Teaching Them

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"Half of your DNA is determined by your mother's side, and half is by your father. So, say if you seem to look exactly like your mother and had gotten all phenotypes from her, perhaps some DNA that codes for your body and how your organs run was copied from your father's genetic makeup."

So close but yet so far. This quote was taken from an essay written by a high school student for the National DNA Day Essay Contest. It reflects just one of the many misconceptions students have in the field of genetics.

In 2006, the American Society of Human Genetics (ASHG; www.ashg.org) began an essay contest for high school students in celebration of DNA Day—an event designed to enhance outreach in schools regarding genetics education. Initially, the contest was designed to encourage students to think seriously about the important implications of human genetics research. Three years and over 3,000 essays later, we have gotten much more than we bargained for.

As our judges began to read essays in detail, it was impossible not to notice the breadth and depth of misinformation and basic misunderstanding. While it was clear that students were being taught the rudimentary scientific concepts of genetics, it was also obvious that many students were not able to translate those concepts into understanding genetics' impact on health or disease.

In an age where information is at our fingertips with the speed of an Internet connection acting as the rate-limiting step to content retrieval, we were hoping to see that students were becoming increasingly empowered to take on the science, technology, engineering, and mathematical challenges of the future.

If the 3,000 essays we have read to date are a reasonable measure of students' preparedness to think critically and analytically, then it is clear that as a scientific community we have a lot of work to do. For those teaching at the undergraduate level, the students writing these essays will soon be in your lecture hall.

We systematically reviewed 500 essays from the first two contests (2006 and 2007) for misconceptions and examples of misinformation. Approximately one-half had at least one error, and 20% had more than one. Students often failed to understand the limits to science—crossing the line between science and science fiction.

Teaching Standards

We suggest that the relatively general nature of curricula supported by national and state science standards result in an oversimplified understanding of genetics. For example, a significant proportion of essays describe genetic determinism, with no role described for gene-environment interactions. Another example is when students attribute any trait to a single gene, instead of understanding that in most cases multiple genes work together (with the environment) to elicit a specific phenotype.

Since most science standards do not include gene-environment interactions or polygenic inheritance, this is not unexpected. It is reasonable to conclude that students are not getting the complete picture of the complexity of biological regulation.

Beyond the content deficiencies, we also noted stylistic concerns. Students write science essays the way they write essays for English class: introductory paragraph, three internal paragraphs, and a conclusion. Students do not understand that words often take on a different meaning in a scientific context and that they need to choose them carefully and precisely. “Proof”, “theory”, “hypothesis”, and “chance” are just some of the words that were repeatedly used in their colloquial context within essays instead of the more rigorous scientific usage.

Science should not be taught in the same way we teach history. Science is not a linear story with a simple start, explanation, and straightforward conclusion. There is an analytical rigor to science, a joy in discovery, and a mystery to be unraveled in almost every fact that a student encounters in a textbook. Yet, we teach our students to read linearly from Chapter 1 to Chapter 35, to memorize vocabulary terms, and answer multiple choice questions that ask students to remember whether A or B leads to C.

Textbooks generally tackle the question of “What do we know?” with ease and accuracy. They rarely provide students the opportunity to experience the process of science, though. Thus, it was not surprising to find that approximately 90% of students fail to address the issue of experimental design, despite the requirement for this element in the published essay contest criteria.

Teachers often teach the way they were taught. If you are still using a lecture hall to lecture and assign chapter readings, your students who ultimately enter a classroom to teach will do the same. We need to break that cycle. We need to teach the way science is done. We need to make sure our students can open a Wikipedia entry or CNN.com and distinguish accuracy from “genohype.”

Revised Education Methods

By teaching science the way science is done, we can also begin to tackle issues related to students’ lack of confidence or trust in scientific information. Students may interpret science that continually changes as information that is not important. Instead, the process of gathering new data, analyzing that data, and identifying what is left to learn are the important pieces that students must be able to apply if they are to internalize, trust, and apply science in their everyday lives.

From the essays we analyzed, it appears that students struggle with how scientists ask and answer questions—the essence of what we do. If they do not understand what we do or how we do it, is there any question why there is concern in the U.S. about a pipeline of future scientists and engineers?

As a scientific community, we need to proactively engage ourselves in K-12 science education. We need to understand the challenges of the K-12 community before we simply criticize and we need to find ways to reward our university faculty for making education a priority.

If we continue to marginalize education and pedagogy, students will continue to lack an understanding of both the essence and excitement of science. We must participate in the earliest steps of the science education process if we expect to engage the brightest and the best to follow in our footsteps.

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