Engaging Non-Science Majors by Integrating Biology and the Liberal Arts

Donna M. Bozzone[1*] and Mary Beth Doyle[2]

Department of Biology[1], Department of Education[2]
Saint Michael's College, 1 Winooski Park, Colchester, Vermont, 05439

***Corresponding Author:** dbozzone@smcvt.edu

Abstract: We describe a pair of fully integrated courses designed to teach biology to non-majors in a manner that connects authentically to the liberal arts. The co-taught courses were organized around the question: What does it mean to be human? Students investigated this question in the context of three topics: dis/ability, race, and sex and gender. In addition, a lab program was integrated in the courses to enhance student understanding of the scientific process and to underscore the necessity of evidence to support all claims and assertions. We also implemented a weekly afterschool science club with children from the Pomerleau Boys and Girls Club. Students, many of whom were science averse prior to taking these courses, thrived. Based on the quality of their writing and class discussion, it was clear that students became increasingly adept at connecting biology to other ways of knowing and to larger issues in their lives. Similarly, they became more skillful at "doing" science in laboratory. Not only did students design and implement interesting experiments, they effectively guided children in their own explorations.

Key Words: co-taught, multidisciplinary, non-major, disability, race, sex and gender

INTRODUCTION

We describe a co-taught, multidisciplinary, integrated pair of courses that invited non-science majors to explore biology in the context of a broad view of the liberal arts. We are convinced that everyone should have a basic understanding of biology and the process of science to function as fully engaged members of society (Holt, 2006).

We designed our integrated courses with non-science majors in mind. As Tobias (1990) characterized in her germinal work, students who do not major in science "are not dumb, they're different." While the focus of her research was to explore how to make the study of science and pursuit of scientific careers more welcoming to a wider swath of students, one can also look at her work in the context of non-science majors who take a science course in order to fulfill a general education requirement or who simply choose to take one because of interest alone. According to Tobias (1990), non-science majors who seriously audited introductory chemistry or physics generally did well in the courses but expressed feeling a lack of engagement in their classroom community. In addition, they wished they had learned more about the connections between science and significant social issues and questions. We recognized that our courses needed to be taught differently than what might be the case for biology majors (Knight and Smith, 2010). The difference in instruction was not a relinquishment of rigor, but rather an acknowledgment that non-majors' biology courses are discrete; there is no expectation that additional biology courses will be taken. In contrast, an introductory biology sequence designed for majors is intended to be the first in a series of courses (Wright, 2005).

We took seriously the need to connect the biology content to broader concerns in meaningful ways (Gilbert & Fausto-Sterling, 2003). One of our goals was to foster an appreciation that biology is a central aspect of modern life. We are convinced that the integration of knowledge—within biology and among the natural sciences, social sciences, humanities, and the arts—is essential for meeting the challenges we all face (Orzel, 2015).

Most students who graduate from college are not science majors; thus, non-majors are the principal pipeline of college graduates entering society (Korn, 2015). In fact, they will be the majority of individuals with the potential to play important roles in helping to find solutions to the problems we must confront such as climate change, emerging diseases, overpopulation, and biodiversity.

Non-science major courses, therefore, serve to prepare better informed citizens rather than to produce professional scientists. Science represents one way of asking questions and evaluating the answers; it is not the only one. Nevertheless, the manner in which scientists explore and learn about the natural world is powerful and effective. Moreover, as a way of thinking, it is a successful approach for many questions, not just scientific ones (Bozzone & Green, 2013).

The primary objective of our integrated courses was to highlight the connections and interdependence among biology, the process of science, and different ways of knowing. We reasoned that understanding biology well insists upon a consideration of the ways that biology connects to the larger culture. In addition, we assert that understanding our culture fully requires familiarity with biology. Indeed, biological research, ideas, and knowledge anastomose with global issues, ethics, and social responsibility (Bozzone & Green, 2013; Fausto-Sterling, 2003). Our aspiration was to teach non-science majors about biology in a manner that will resonate meaningfully in their lives (Pain, 2010). The main goal of this paper is to provide instructors with a potential pedagogical approach to help them capture more fully the interests of their non-science major students.

METHODS

Course Design and Implementation

At Saint Michael's College, a full-time course load is the equivalent of 16 credits per semester. Courses are typically four credits; therefore, full time students take 4 courses per term. All students are required to take a First-Year Seminar and a lab science course as part of their general education. The course described in this paper is a fully integrated combination of First Year Seminar (4 credits) and Biology Lab Science (4 credits). It is important to note that while the courses are integrated both in their design and implementation, students earn two separate grades. The individual grades are linked to objectives and assignments that are specific to the individual courses. This division was necessary in order to align with the traditional college structure related to student assessment and transcript records.

Each individual class met twice per week for 95 minutes. The two courses were scheduled to meet consecutively in the same classroom equaling total class meetings of two continuous 190 minute sessions per week. Given the structure of the course, the lab was integrated within the meetings. We had the opportunity to teach the entire course in a laboratory that was also suitable for discussion. Consequently, we were able to weave laboratory investigations into every class meeting.

As we designed the course, we had several specific teaching objectives in mind. First, we chose to help students enhance their understanding of the process of science. In order to do so, we explored topics using an inquiry-based approach. In addition, students engaged in hands-on discovery and investigation in laboratory. Second, we were determined for students to have the opportunity to enhance their appreciation of the human dimension of science (Chamany, *et al*., 2008). We wanted them to appreciate that everything ever discovered or solved is literally the result of a person or many people thinking that the question being pursued was the *most* interesting and important thing to be found. They simply *had* to work on this problem—it was like an itch that had to be scratched. We wanted students to feel the emotional connection that people can have with learning and discovery, and hopefully to experience it themselves (Olitsky & Milne, 2012). And third, we wished to emphasize and have students understand that the integration of knowledge not simply within biology, but also among the sciences and the liberal arts in general, is essential in the world of the 21st century (Bozzone & Green, 2013).

To achieve these objectives, the course focused on the question: What does it mean to be human? More specifically, is humanness a socially constructed entity, is it biologically determined, or an emergent property that is a consequence of both? We taught students how to examine these questions through a lens of determinism versus one of potential. Determinism is a perspective that focuses on limits. If something is determined, there is no altering the fate or outcome. Many students think, incorrectly, that biology operates this way. In contrast, looking at a situation from the stance of potential means fewer limits. Consider this example: Suppose a person was born with all of the biological risk factors in place for becoming an alcoholic. Some might see this person as doomed to abuse alcohol because they are biologically determined to do so. But what if this person was an observant Mormon and therefore never drank alcohol? They would never abuse alcohol. So, to be more accurate, this person had the potential to be a substance abuser, they were not determined to be so.

We recognized that while considering a problem with a reductionist set of tools is powerful, it does not provide the whole picture; we designed and taught the course accordingly. Similarly, examination of a question like the meaning of humanness from a singular vantage point (e.g. biology, sociology, history) is insufficient. Instead, we privileged attention to the interactions of life science, social science, and humanities in the exploration of this question.

We designed three specific topic units to animate our exploration of the questions about being human: dis/ability; race; and sex and gender. For each unit, students were assigned a book length narrative to ground our investigations in the experiences of actual lives (Appendix 1). In addition, students read and discussed historical narratives to answer the questions: "What did *learned* people once think about this issue? Why? What did these learned people once think were *facts*?" Students examined these questions from both social and biological perspectives.

Next, students read and discussed current accounts of what learned people "know". Within this framework, students explored both the sociological and biological explanations of our time. Once again, we prompted students to consider the intersections of schools of thought therein making explicit connections between potential versus deterministic argumentation.

Finally, having learned from historical and modern narratives, students were challenged to answer the questions: "Is there a biological basis to the characteristics we are considering? Whether or not there is, how does the characteristic influence the human experience? Can you imagine how learned people in the future might consider these questions? What are you left wondering about? What part of your answers are you confident in versus what is provisional?"

Biological Concepts

Students were introduced to specific biological concepts at appropriate junctures. From our perspectives, student

Table 1. Examples of Biology and Science Concepts Integrated in the Course

Foundational Unit
• Process of science • Biological determinism • Biological potential • Evolutionary contribution to social behavior in humans • Eugenics
Dis/ability
• Meiosis • Inheritance • Human embryogenesis • Biology of Down syndrome • Central dogma • Relationship between genes and phenotype
Race
• Evolution • Human variation • Biology of skin color • Biology of race • Mitosis • Cancer
Sex and Gender
• Historical views of women's bodies and development • Sexual development • Disorders of or differences in sexual development: Androgen insensitivity syndrome (AIS), Congenital adrenal hyperplasia (CAH), Guevedoces (5-alpha reductase deficiency) • Sexual orientation • Transgender people • Sex verification tests in sports

understanding of biological topics was foundational for a substantive examination and analysis of the big question of what it means to be human, as well as the particular topics of each course unit. To have a multidimensional understanding of Down syndrome, the specific dis/ability upon which we focused in the first topic unit, students needed to learn about cells, inheritance, meiosis, mutation, information transfer from DNA to protein, how phenotypes arise, and human development. We returned to many of these concepts in our Race, as well as Sex and Gender units, thus reinforcing understanding and comfort with these biological topics. The Race unit also warranted consideration of evolution, as well as a direct look at whether there is a biological basis to race at all. The Sex and Gender unit invited an examination of sexual development, gene expression, and how hormones elicit biological responses.

Biological concepts (Table 1) were woven into the course by a series of mini-lectures, hands-on activities, simulations, directed readings, and writing assignments. For example, in our consideration of Down syndrome, students were provided direct instruction about typical and atypical meiosis. These concepts were reinforced with a hands-on exercise in which students used physical manipulatives (i.e., pipe cleaners) to demonstrate their understanding of this type of cell division. The directed readings in this included the book length narrative (i.e., *The Shape of the Eye*) and specific readings pertaining to biological, medical, and social aspects of Down syndrome (Appendix 1). Examples of student products from this unit included a pamphlet about Down syndrome intended for community outreach and a poster presentation (Table 2). This biological knowledge formed a significant and essential component of our working vocabulary providing us with a common language.

Laboratory Program

The best way to learn about the process of science authentically is to actually "do" it. Given our emphasis on the power of science to address certain types of questions and its insistence for empirical validation of claims, we designed a lab program, which allowed students to do original investigations, fostered a healthy skepticism, and reinforced the practice of providing evidence to support assertions (Table 3). This habit of thought served as an anchor for the entire course as it helped students to ask, when confronting an assertion in the readings (assigned or otherwise), in discussion, or even in conversation—*How do we know this? Is this statement supported by reliable evidence?* By practicing science—making

Table 2. Examples of Student Products

Foundational Unit
• Essay: What does educational research reveal about whether class attendance is important? • Essay: What does it mean to "other" someone? On what bases do we other? • Essay: Compare and contrast the concepts of biological determinism and biological potential • Essay: Reflect on the question of what it means to be "normal".
Dis/ability
• Notebook: Write two chronologies of the events described in *The Shape of the Eye* • Pamphlet: What is Down syndrome? • Short, reflective essay for every class
Race
• Book Club: Prepare for discussion of *The Immortal Life of Henrietta Lacks* • Debate: prepare material to debate whether there is a biological basis to race • Short, reflective essay for every class
Sex and Gender
• Discussion preparation: Lead discussion of specific chapters of *Sex/Culture: Biology in a Social World* • Debate: Prepare materials to debate whether sex testing of elite female athletes is necessary for fair competition • Short, reflective essay for every class
Lab Program
• Lab notebook with all records of experimental work including science fair projects • *Physarum* research poster • Sow bug research poster • Bess bug research poster • Science Fair Poster

Table 3. The Integrated Lab Program

***Physarum polycephalum* (3 weeks)**
• Introduction to organism • Pilot experiments to study chemotaxis • Additional experiments to explore phototaxis, chemotaxis, migration patterns in response to barriers, mapping behaviors, and the ability to solve simple mazes
Sow bugs (2 weeks)
• Introduction to the organism • Pilot experiments to test choice of environments • Additional experiments to investigate food preferences, velocity of movement, selection of preferred temperatures; selection of preferred light conditions, and ability to solve simple mazes
Bess bugs (2 weeks)
• Introduction to the organism • Pilot experiments to test the ability of bess bugs to pull weight • Additional experiments to explore parameters (incline, friction, size of bess bug, for example) on weight pulling ability, factors affecting crawling speed, ability to solve simple mazes, and climbing ability
Projects and Science Fair (4 weeks)
• Guided by the college students, children did an independent project that addressed a testable question of their own with *Physarum*, sow bugs, or bess bugs

observations; wondering; exploring; posing testable questions; formulating hypotheses; implementing studies to test hypotheses; analyzing results; and formulating new questions—students enhanced their capacities to reason analytically.

The laboratory program consisted of four units (Table 3). During the first unit, which was three weeks in length, students explored the growth and development of the plasmodial slime mold *Physarum polycephalum.* We chose *Physarum* as a study organism because it is easy to culture and handle and therefore suitable for novice students (Bozzone, 2005). Moreover, we reasoned that *Physarum* would engender student interest because it displays interesting and easy to measure behaviors such as chemotaxis, phototaxis, and simple problem solving such as avoiding barriers, completing mapping problems, and negotiating mazes (Adamatzky & Jones, 2010; Bohland *et al*., 2011; Nakagaki, *et al*., 2000).

During the first week of the unit, students made observations of *Physarum* and set up basic experiments to address questions about chemotaxis (Bozzone, 2005). The main objective of this work was to introduce students to the process of science. The second week of the unit entailed setting up experiments to address new questions that derived from their initial results. During the third week, students analyzed their data, discussed their findings with the entire class, and prepared a research poster to display their work.

Units two and three of the lab program followed a similar plan: introduction to an organism; simple experimentation to learn how to handle the organism; designing experiments; collecting data; analyzing data; articulating and addressing another experimental question; and presenting the results of their work in the forms of lab reports and posters. For unit two, students explored *Porcellio laevis* (sow bugs) behaviors (Mikula, 2000; Olsson, 2004) and for unit three, *Passalus cornutus* (bess bugs) (Anon, 2016; Gardner, 2005).

Community Connection

One important feature of the lab program was our engagement with a community partner, the Pomerleau Boys and Girls Club of Burlington, Vermont. We engaged in lab work every class. The first meeting of each week involved the college students undertaking their explorations and experiments. In the second meeting, they were joined by middle school children from the Boys and Girls Club (ages 9-12). This afterschool science program was scheduled to coincide with the Club's afterschool activities. The ratio of college students to children was 2:1. The rationale for including a community partner was that we wanted our students to reinforce their learning by teaching others, to experience that learning is also about giving not just taking, and to feel the confidence that comes from being an expert.

The culminating event of the lab program was a science fair. Our students mentored the children each of whom completed an original investigation with one of the three experimental systems we studied: *Physarum*, sow bugs, or bess bugs. The science fair was held at the College. We invited families and friends of the children, as well as staff and administrators from the Boys and Girls Club. In addition, we welcomed students, faculty, and administrators from the College.

First Year Seminar Objectives

The First Year Seminar (FYS) program at our college is rooted in the combination of writing and discourse. The topics of the FYS program vary (e.g., Peace and Justice, Robotics, the Examined Life), but the instructional objectives are the same. All sections include an emphasis on writing and the topics studied encourage examination of large questions within an interdisciplinary dimension. The courses require frequent writing, at least twice per week. The writing is both formal and informal.

We used writing as a key tool for teaching and learning (Stockwell, 2016). With respect to the writing process, we had specific goals woven within our integrated FYS/BI course. First, we wanted to enhance students' abilities to manage the writing process (i.e., prewriting, drafting, feedback, revision, editing, and proofreading) in order to produce finished products. Second, we worked with students to improve their abilities to generate a thesis on their own and to support it with convincing evidence and reasoning in a formal academic essay that has cohesion, coherence, and voice. Third, we taught students how to apply basic research skills (e.g., library research, archival research, construction of thesis).

We taught students how to engage in active reading (e.g., reverse outlining, text to speech software, summarizing) and how to write for different purposes (e.g., review of literature, expository writing, and reflective essays). We assessed learning by evaluating student work at various stages of completion; students generated writing portfolios. The assessment tool used for all written pieces was the College approved writing rubric.

OUTCOMES

There were four overarching objectives for this course, which were re-visited for each unit, allowing students to deepen both their content knowledge and ability to engage with complex information. Following are descriptions of each learning objective and the corresponding evidence that students met them.

The first objective was *students will generate connections between biology, the liberal arts, and their lived experiences*. Because we led with narrative, embedded each topic in an historical context, and intentionally connected the biology to actual lives and the larger world, students became skillful at migrating between various ways of knowing and seeing the bigger, interconnected picture. For example, our considerations of race transformed the views that students had about the biological basis of this human characteristic. They came to understand the fundamental unity of life at the biological level. They made connections between what they learned about cells, cell division, and cancer with the lived experiences of Henrietta Lacks. In doing so, they saw, for the first time, the inseparable connections between biology and the lived experiences of *all* people. As one student wrote, “The ways we relate the scientific aspect to the relevant issues in society are insightful and eye opening.” Yet another wrote, “Our in-class discussions were thoughtful and thought provoking and now I understand science and biology in a way that I hadn’t prior to the class.” These quotes were illustrative of the comments on all of the course evaluations. As a matter of fact, students rated this course combination higher than the College mean or either of the authors’ department means, on every parameter. With respect to suggestions for course or instructor(s) improvement, students did not offer any and were unanimous in wishing that there were more courses designed and taught this way.

The second objective was *students will demonstrate the process of science and inquiry*. While the lab program was the most explicit way in which students met this objective, the type of analysis and reasoning developed therein raised the quality of student writing and discussion. With respect to the lab, students were able to pose testable questions, design and implement experiments to address them, and to analyze and interpret their data. Most important, they were able to generate new questions based upon their results, as demonstrated by novel experiments. Moreover, lab notebooks and final posters were graded for content accuracy, analysis, and presentation. One student wrote, “Throughout this semester, I feel as though I have gotten better (in science) and am able to teach children, even if I did not believe that I was very good at science in high school.”

The third objective was *students will write for a variety of audiences and purposes at the college level*. Students generated a rich array of writing products including reflective essays, research essays, notes based on reading and research, data tables and figures, posters, and educational pamphlets (Table 2).

The fourth objective was *students will engage in community outreach in the form of an after-school science club*. Ten children from the Boys and Girls Club participated in a weekly science club led by the college students. Both the children and college students derived benefit from the experience. Children from the Boys and Girls Club had been participating at the College for the four previous years. The activities during that time focused on assistance with homework followed by play. Historically, attendance was inconsistent and periodically the children exhibited behavioral challenges. Since we initiated the science club, the children simply never missed. As one college student observed, “At first I thought they (Club kids) had no interest. However, they clearly progressed and became more involved and engaged… in the beginning it was obvious children were not comfortable, in the end they wanted to do all of it themselves and they were coming up with questions without prompting.” Moreover, because there were a limited number of slots, there was a waiting list for additional children.

The college students took seriously the importance of preparation so that they knew, understood, and practiced the biology concepts and experiments in order to be effective for the children. Furthermore, the science club enhanced the learning experiences of the college students. For example, one student wrote, “Having to use the scientific process in a way to help the kids learn the experiments helped me learn the scientific process to a greater extent.” Another student wrote, “Working with the Club kids has been a great opportunity to pass on my new-found appreciation of science. I was so thrilled by the results of the science fair and the fact that the kids loved showing off their projects.”

CONCLUSION

Our experiences with this integrated course were more successful for both our students and for us than we had imagined they could be. We think that the principle reasons for this success were our decisions to focus on the power of narrative and our commitment to co-teaching. In doing so, we observed that students engaged in thoughtful informed discussion. Interestingly, it was the focus on the stories of lived experiences that prompted students to ask substantive questions about biology and the process of science in order to become more informed about the topics within the narratives. Over time, their questions sharpened and became more nuanced and sophisticated. As they moved from unit to unit through the course, they became increasingly skillful at investigating and mastering the biological concepts and foundations pertaining to the topics we were discussing. With reference to the co-teaching, students benefitted from the shared preparation, delivery, and assessment of every unit. Class discussions were enriched markedly because of the two lenses (life science and social science) through which we approached each topic.

It was a surprise to us to see that students were able to achieve analysis and synthesis levels of understanding without engaging in rote memorization. In fact, they demonstrated their capacities to access the content necessary to push the discussions and research further than we had planned. Over time, this was reinforced in our deliberate questioning cycle: How do you know this? What else do you need to know? What would happen if? (Figure 1) What was astounding to us was the impact of this approach on student curiosity and desire to learn.

Also surprising was the impact on us as faculty with a combined tenure of more than 50 years of teaching at the college level. This course combination opened up the opportunity for us to engage in new fields of study, integrate those areas of study into our own territories of expertise, and learn new pedagogical approaches and techniques.

Looking to the future, we will continue to offer this course and investigate the short and long term effects of this approach on student motivation for and attitudes toward studying science (Cook & Mulvihill, 2008; Glynn *et al*., 2009; Handelsman *et al*., 2005; Lovelace & Brickman, 2013; Moore & Foy, 1997). Finally, under the auspices of the Center for Teaching and Learning at our college, we have established a faculty discussion group on the topics of cross-disciplinary co-teaching and collaboration in higher education.

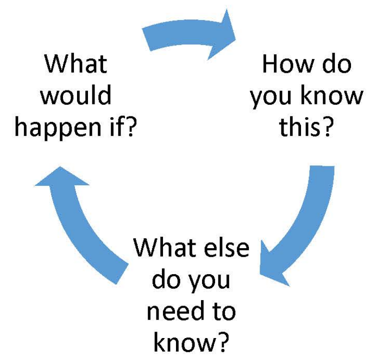

Fig. 1. Questioning Cycle

ACKNOWLEDGMENTS

We would like to thank Dottie Dearborn of the Pomerleau Boys and Girls Club of Burlington Vermont for her tireless advocacy for the children and youth of the community.

REFERENCES

ADAMATZKY, A. AND J. JONES. 2010. Road planning with slime mold: If *Physarum* built motorways it would route M6/M74 through Newcastle. *Int. J. Bifurcation Chaos* 20 (10): 3065- 3084.

ANON. Simple science: Bess bug test of strength. Accessed from http://earthsbirthday.org/images/uploads/bugs/bessbug-test-of-strength.pdf on 1 June 2016.

BOHLAND, C.E., SCHMALE III, D.G., AND S.D. ROSS. 2011. Caging the blob: Using a slime mold to teach concepts about barriers that constrain the movement of organisms. *American Biology Teacher* 73 (9): 537-541.

BOZZONE, D. M. 2005. Using microbial eukaryotes for laboratory instruction and student inquiry. In O'Donnell, M.A. *Tested Studies for Laboratory Teaching, Volume 26, Proceedings of the 26th Workshop/Conference of the Association for Biology Laboratory Education (ABLE*), 452 p.

BOZZONE, D.M. AND D.S. GREEN. 2013. *Biology for the Informed Citizen with Physiology*. Oxford University Press, New York. 584 p.

CHAMANY, K., ALLEN, D., AND K. TANNER. 2008. Making biology learning relevant to students: Integrating people, history, and context into college biology teaching. *CBE Life Sci. Educ*. 7: 267-278.

COOK, M. AND T.M. MULVIHILL. 2008. Examining US college students' attitudes towards science: Learning from non-science majors. *Educational Research and Review* 3 (1): 38-47.

FAUSTO-STERLING, A. 2003. Science matters, culture matters. *Perspectives in Biology and Medicine* 46 (1): 109-204.

GARDNER, K. 2005. Are you stronger than an insect? A comparative look at form, structure, and strength. Accessed from http://csip.cornell.edu/Curriculum_Resources/CSIP/Gardner/Gardner.html on 1 June 2016.

GILBERT, S.F. AND A. FAUSTO-STERLING. 2003. Educating for social responsibility: Changing the syllabus of developmental biology. *Int. J. Dev. Biol*. 47: 237-244.

GLYNN, S.M., TAASOOBSHIRAZI, G., AND, P. BRICKMAN. 2009. Science major questionnaire: Construct validation with non-science majors. *Journal of Research in Science Teaching* 46 (2): 127-146.

HANDELSMAN, M.M., BRIGGS, W.L., SULLIVAN, N., AND A. TOWLER. 2005. A measure of college student course engagement. *Journal of Educational Research* 98 (3): 184-192.

HOLT, R. 2006. Science and citizenship. *Social Research: An International Quarterly* 73 (3): 1037-1041.

KNIGHT, J.K. AND M.K. SMITH. 2010. Different but equal? How non-majors and majors approach and learn genetics. *CBE Life Sci. Educ*. 9 (1): 34-44.

KORN, M. 2015. Number of students pursuing science, engineering stagnates: Push to increase workers' skills has little effect. Accessed from www.wsj.com/articles/number-of-college-students-pursuing-science-engineering-stagnates-1422334862 on 29 June 2017.

LOVELACE, M. AND P. BRICKMAN. 2013. Best practices for measuring students' attitudes toward learning science. *CBE Life Sci. Educ*. 12: 606-617.

MIKULA, T. 2000. Isopod inquiry. *The Science Teacher* 67: 20-22.

MOORE, R.W. AND R.L.H. FOY. 1997. The scientific attitude inventory: A revision (SAI II). *Journal of Research in Science Teaching* 34 (4): 327-336.

NAKAGAKI, T., YAMADA, H., AND A. TOTH. 2000. Intelligence: Maze-solving by an amoeboid organism. *Nature* 407 (6803): 470.

OLITSKY, S. AND C. MILNE. 2012. Understanding engagement in science education: The psychological and the social. In Fraser, B. J., Tobin, K., and McRobbie, C. *Second International Handbook of Science Education,* Dordrecht, Netherlands, 1564 p.

OLSSON, S. 2004. The wonderful world of isopods. Accessed from csip.cornell.edu/Curriculum_Resources/CSIP/Olsson/Olsson_Isopod.html on 1 June 2016.

ORZEL, C. 2015. Why every college student needs to take science course. Accessed from www.forbes.com/sites/chadorzel/2015/09/10/why-every-college-student-needs-to-take-sicne/#2038cadf6a36 on 20 April 2016.

PAIN, E. 2010. Teaching science to nonscience majors. Accessed from www.sciencemag.org/careers/2010/04/teaching-science-nonscience-majors on 20 April 2016

STOCKWELL, S.B. 2016. A progressive reading, writing, and artistic module to support science literacy. *Journal of Microbiology and Biology Education* 17 (1): 93-97.

TOBIAS, S. 1990. *They're Not Dumb, They're Different: Stalking the Second Tier (Occasional Paper on Neglected Problems in Science Education)*. Research Corporation, Tucson, Arizona. 94 p.

WRIGHT, R.L. 2005. Undergraduate biology courses for nonscientists: Toward a lived curriculum. *Cell Biol. Educ*. 4(3): 189-196.

Appendix 1. Examples of Assigned Readings and Instructional Resources

Foundational Unit

Reading Assignments:

- Bozzone, D.M. and D.S. Green. 2013. *Biology for the Informed Citizen*. Oxford University Press, New York 584 p.
- Gilbert, S.F., Tyler. A.l., and E.J. Zackin. 2005. What is "normal"? in *Bioethics and the New Embryology: Springboards for Debate*. Sinauer, Sunderland, MA. 299 p.
- Konnikova, M. 2014. The limits of friendship. *The New Yorker*. Accessed from http://www.newyorker.com/science/maria-konnikova/social-media-affect-math-dunbar-number-friendships on 5 May 2016.
- Moore, R. 2003. Attendance and performance: How important is it for students to attend class? *Journal of College Science Teaching* 32(6) 367-371.

Additional Resources:

- Association of American Colleges & Universities description of a liberal education: https://www.aacu.org/leap/what-is-a-liberal-education
- Rethinking 'normal' and 'abnormal': https://www.psychologytoday.com/blog/rethinking-psychology/201111/what-do-we-mean-normal

Dis/ability

Reading Assignments:

- Admundson, R. 2000. Against normal function. *Studies in History and Philosophy of Biological and Biomedical Sciences 31*(1) 33-53.
- Allen, G.E. 2001. Is a new eugenics afoot? *Science 294*(5540) 59-61.
- Estreich, G. *Shape of the Eye: A Memoir*. Penguin Publishing Group: New York. 314 p.
- Lalvani, P. (2015). "We are not aliens": Exploring the meaning of disability and the nature of belongingness in a fourth grade classroom. *Disabilities Studies Quarterly 35*(4).
- McCabe, L.L., and E.R. McCabe. (2011). Down syndrome: Coercion and eugenics. *Genetics in Medicine. 13*(8) 708-710.
- Clark, P. and L. Vasta. 2006. The Ashley treatment: An ethical analysis. *The Internet Journal of Law, Healthcare and Ethics*. 5(1): 1-12.
- Smith, S.E. 2012. Is the Ashley treatment right? Ask yourself if disabled people are human. Accessed from https://www.theguardian.com/commentisfree/2012/mar/16/ashley-treatment-disabled-people on 7 Apr 2016.
- Becker, A.J. 2013. The social construction of selective abortion. Accessed from https://www.theatlantic.com/sexes/archive/2013/01/the-social-construction-of-selective-abortion/267386/ on 22 Mar 2016.

Additional Resources:

Media portrayals of people with Down syndrome:

- TED Talk: https://www.youtube.com/watch?v=SxrS7-I_sMQ
- Down Syndrome: https://vimeo.com/165816886
- Down Syndrome: https://www.popsugar.com/beauty/Model-Down-Syndrome-Beauty-Interview-Video-40985630
- Down Syndrome: https://modernmessy.wordpress.com/category/portrayals-of-down-syndrome-in-media/

University and Academic site resources:

- Vanderbilt University: https://iris.peabody.vanderbilt.edu/films/
- Otterbein College: http://www.otterbein.edu/public/Library/erin-mckenzie/dedication.aspx
- University of Washington: https://disabilitystudies.washington.edu/
- Cold Spring Harbor Laboratory: http://www.eugenicsarchive.org/eugenics/
- University of Virginia: http://exhibits.hsl.virginia.edu/eugenics/3-buckvbell/

National Organizations:

- Special Olympics: http://www.specialolympics.org/uploadedFiles/LandingPage/WhatWeDo/Research_Studies_Description_Pages/Policy_paper_media_portrayal.pdf
- National Down Syndrome Society: http://www.ndss.org/About-NDSS/Media-Kit/
- Howard Hughes Medical Institute: http://www.hhmi.org/biointeractive/human-embryonic-development
- Centers for Disease Control: https://www.cdc.gov/ncbddd/birthdefects/downsyndrome/data.htm

Race

Reading Assignments:

- Bhopl, R. 2007. The beautiful skull and Blumenbach's errors. *British Medical Journal 335* 1308-1309.
- Green, V.H. 2016. *The Negro Motorist Green-Book: 1940 Facsimile Edition*. About Comics.
- Skloot, R., 2011. *The Immortal Life of Henrietta Lacks*. Broadway Paperbacks: New York. 381 p.

Additional Resources:

Media portrayals:

- Henry Louis Gates, Jr.: https://www.youtube.com/watch?v=phcqu8rNZ9Q
- Henry Louis Gates, Jr.: https://www.youtube.com/watch?v=nw43kWEKjn8

University and Academic Resources:

- Howard Hughes Medical Institute: https://www.youtube.com/watch?v=VC0TL_lYLm8
- Science of Skin Color: https://www.youtube.com/watch?v=VC0TL_lYLm8
- Myth of Race: https://www.youtube.com/watch?v=VnfKgffCZ7U
- Patenting Human Gene: https://www.youtube.com/watch?v=r_xV-M0KPo0
- TED Talk: https://www.youtube.com/watch?v=_r4c2NT4naQ

Sex and Gender

Reading Assignments:

- Fausto-Sterling, A. 2012. *Sex/Gender: Biology in a Social World*. Routledge, New York. 142 p.
- Gladwell, M. and N. Thompson. 2012. Caster Semenya and the logic of Olympic competition. Accessed from www.newyorker.com/news/sporting-scene/caster-semenya-and-the-logic-of-olympic-competition.

- Healy, M.L., Gibney, J., Pentecost, C., Wheeler, M.J., and P.H. Sonksen. 2014. Endocrine profiles in 698 elite athletes in the post competition setting. *Clinical Endocrinology* 0: 1-12.
- Karkazis, K. and R. Jordan-Young. 2012. The contrarians: Stop policing testosterone in female athletes. Accessed from www.discovermagazine.com/2012/nov/03-the-contraians-katrina-karkazis-and-rebecca-jordan-young on 2 Dec 2013.
- Karkazis, K. and R. Jordan-Young. 2014. The trouble with too much T. Accessed from www.nytimes.com/2014/04/11/opinion/the-trouble-with-too-much-t.html?_r=0 accessed 29 Aug 2016.
- Michaels, S. 2016. The biggest issue in women's sports is about to come to a head. Accessed from www.motherjones.com/print/310831 accessed on 11 April 2017.
- Vilain, E. 2012. Gender testing for athletes remains a tough call. Accessed from www.nytimes.com/2012/06/18/sports/olympics/the-line-between-male-and-female-athletes-how-to-decide.html?_r=0 on 18 Aug 2016.
- Viloria, H.D. and M.J. Martinez-Patino. 2012. Re-examining rationales of "fairness": An athlete and insider's perspective on the new policies on hyperandrogenism in elite female athletes. *The American Journal of Bioethics* 12(7): 17-33.

Additional Resources:
Media Portrayals:

- Nature vs Nurture: https://www.psychologytoday.com/blog/sexing-the-body/201007/nature-versus-nurture-part-1-it-s-time-withdraw-war
- Nature vs Nurture: https://www.psychologytoday.com/blog/sexing-the-body/201008/nature-versus-nurture-part-2-building-brains
- Sexuality: https://www.psychologytoday.com/blog/sexing-the-body/201111/are-we-born-gay.
- Intersex: Part 1 of Growing Up Intersex, The Oprah Winfrey Show, with members of the AIS-DSD Support group. June 5, 2007.
- Guevodoces: https://vimeo.com/145344626