Multidisciplinary Teaching: Providing Undergraduates with the Skills to Integrate Knowledge and Tackle "Big" Questions

By Mary Beth Doyle and Donna Bozzone, Saint Michael's College

Introduction

The overarching goals of undergraduate education are to engender in students the capacity to think deeply, analyze information, and integrate important ideas in a context which is situated in a disciplinary foundation and connected to lived experiences. Looked at more closely, we wish for students to engage in asking important, big questions; this is not so easy to do. Why? One answer might be that we teach as if knowledge is discrete and compartmentalized. It is not. In fact, the most enjoyable and reinforcing aspects of learning are seeing and experiencing the connections between different subject areas. And yet, in many colleges and universities we teach in ways that mask this reality from students. Professors teach as if in silos and engage in the magical thinking that our students will make these connections themselves. We decided to address the challenge students face trying to see how topics from different disciplines are authentically interconnected. To do so, we stepped out of our individual disciplinary comfort zones (social science and life science) and developed a co-taught, multidisciplinary course, organized around the question: what does it mean to be human?

Although our course philosophy, design, pedagogy, and implementation are generalizable and learning in this way is accessible to students of any major, we designed our integrated course with non-science majors in mind. Such students possess perspectives, interests, dispositions, and expectations that differ somewhat from most students majoring in biology (Sundberg and Dini, 1993; Cook and Mulvihill, 2008) and that is what makes it so much fun and so rewarding to teach them. These differences in student populations, however, mean that non-majors biology courses can be taught differently than those intended for majors. Different does not mean "dumbing down" but rather recognizes there is a fundamental distinction between introductory courses taught for majors and those taught for non-majors (Wright, 2005; Knight and Smith, 2010). We reasoned that focusing on non-majors biology would provide us greater freedom for pedagogical creativity and innovation. To be specific, the introductory course sequence designed for biology majors is intended to be the first in a series of courses, while non-major biology courses are more discrete: there is no expectation that additional biology courses will be taken. In addition, we encouraged elementary education majors to enroll in the course given their well-documented fears of science (Tosun, 2000). Our hope was that by experiencing an integrated approach to learning the students would engage more readily and with less trepidation.

Course Design

The primary objective of our integrated course was to engage students in the study of biology and the process of science in a manner that highlights the connections and interdependence of different ways of knowing. This objective derived from the fact that biology does not exist as a disconnected field of study. Therefore, in order to understand biology well, one needs to be conversant with the ways that biology connects to the larger culture. The inverse is also true: to understand our culture fully, one needs to be familiar with biology. More specifically, biological research, ideas, and knowledge intersect with global issues, ethics, and social responsibility (Bozzone and Green, 2014). The overarching hope of our course was to teach students about biology in a way that will have meaning and relevance for their lives.

Although we designed and taught this course as one integrated offering, for the purpose of the Registrar's records, students enrolled in two courses (i.e., First Year Seminar and Biology Lab Science) and were assigned grades for each.

To address our guiding question: what does it mean to be human?, we combined a First Year Seminar, "The Social Construction of Humanness" and a non-majors lab course, "The Cell and Developmental Biology of Being Human." Both courses fulfill general education requirements at the college. The principle objectives of First Year Seminar are close reading, discussion, and writing at the college level and that of the biology course is to engage students in the scientific process. Our class met for three hours twice per week with an embedded lab component.

With respect to course content, we focused on three aspects of diversity: race and culture; dis/ability; and sex and gender (refer to Table 1). We paid particular attention to the phenomena of "othering" and marginalizing those who are different from ourselves. We explored these topics from social science and biological perspectives. From the social science vantage point we examined the impact of our individual and collective experiences and responses to the three aspects of diversity studied in relationship to the foundational question, what does it mean to be human? For example, in the dis/ability unit we addressed the questions: Do individuals with Down syndrome have the same inherent value as those without? Should individuals with Down syndrome have the same rights, responsibilities, and opportunities as those without? From a biological perspective, consideration of these topics required a close examination of inheritance, information flow within cells and organisms, cell structure and function, development, and evolution. Examples of questions we examined included, what mechanistic explanations are there to account for Down syndrome? Can the experiences of individuals with Down syndrome be explained as outcomes of their biology?

Table 1. Examples of Primary Concepts for the Disability Unit: Down syndrome Case

Biology Concepts	First Year Seminar Concepts
Meiosis	Accessibility
Mitosis	People First Language
Human Embryogenesis	Legal Rights and Responsibilities
Anatomy	Determinism vs Potential
Evolution and variation	Social Constructs of Dis/ability
Chromosomes	Family Systems and Networks of Support
Inheritance	Disability Rights
Genotype and phenotype	Othering and Marginalization

We chose a deliberate and consistent instructional approach that was repeated for every unit. We began with formative assessments including discussions, electronic polling, graphic organizers, board work, and free-writes. Based upon what we learned from the formative assessment, we designed instruction that included: videos, accessible readings typically from articles in credible popular press (e.g., *The New Yorker*), discussion, and informal student writing, after which we inserted primary literature. Given the complex nature of primary literature, we scaffolded directly through reverse outlining (Brizee, 2010) how to negotiate and prepare challenging reading assignments. We then re-visited the initial questions and students discussed their growth based on the new information. Our goal was to deepen and enhance their understanding and to invite curiosity.

To illustrate our approach in more detail, we describe below its application for the sex and gender unit. Using a case study to humanize the topic, we introduced the story of Caster Semenya.

Caster Semenya, a world class track and field athlete, was subjected to medical tests to verify she is a woman (Levy, 2009). These so called "gender tests" were done to determine whether Semenya was eligible to compete as a woman. She endured intense public scrutiny; had her private life displayed on media throughout the world, without her permission; and was mocked by other athletes and sports announcers. Semenya became so despondent she wished to die. Her case allowed us to address both biological and social questions about sex and gender directly. While the detailed results of her medical tests were never released officially, Caster Semenya probably has atypical sexual development (Levy, 2009). Biological concepts that we explored included embryogenesis, gene function, sex determination in humans and other organisms, and typical and atypical sexual development. Topics explored through the social science lens included social and historical gender testing in sports, the intersection of gender testing and race, gender as a social construct, the social and societal challenges experienced by a person like Semenya, who does not fit neatly within a gender or sex binary, and ultimately, what are sex and gender.

The primary text used to support this unit was *Sex/Gender: Biology in a Social World* (Fausto-Sterling, 2012). Additional readings, videos, and documentaries were also assigned. Topics of class discussion included: the history, implementation and outcomes of Title IX; historical views of women's bodies starting from ancient works; three specific DSDs (differences in, or disorders of sexual development): AIS (androgen insensitivity syndrome—most likely the DSD experienced by Semenya), CAH (congenital adrenal hyperplasia), and Guevedoces (5-alpha reductase deficiency); sexuality; and gender.

Students were surprised to learn about these DSDs. Individuals with AIS have X and Y sex chromosomes. Typically, such genetic instructions contribute to the development of males. The cells of individuals with AIS are missing receptors to bind a sex hormone that is necessary for the development of bodies that look male. Individuals with AIS develop bodies that are externally female. CAH is a DSD in which the developing embryo or fetus is exposed to high levels of sex hormones. If the embryo is XX, meaning possessing the chromosomes associated with the development of a girl, her external genitals will become "masculinized". Guevedoces refers to a DSD in which the individuals are XY, are identified as girls at birth, and who develop external male genitals at the time of puberty. Guevedoces translates roughly to "penis at twelve". This exploration of typical and atypical sexual development, both the biology and the social outcomes for individuals with DSDs, was eye-opening for students. They realized, for example, that nature is not so discrete either and that categories are made by people. Similarly, social categories and the related roles individuals are expected to play are also not discrete. And these groupings, too, are made by people as well.

Products generated by student work included articulating definitions of female, male, feminine, masculine, homosexual, bisexual, and heterosexual; hands on demonstrations of mitosis and meiosis; analyses and discussions of assigned articles, online sources, and videos; reflective writing after each class meeting; and responsibility to prepare for and facilitate discussion of a specific assigned chapter of the text. The culmination of this unit was a debate about sex and gender testing for which students were asked to call upon their previous learning from the course and their reading of three additional papers to prepare and support their arguments.

Outcomes: Students and Faculty

Students

Students in this course met or exceeded our learning objectives and hopes. Specifically, they enhanced their skills in approaching primary literature; engaged in substantive debate in which they moved beyond providing personal opinion; evaluated and supported arguments with evidence; and enhanced writing effectiveness. They also exhibited an enlivened curiosity and desire to go beyond the surface view and to dig for mechanistic explanation. Moreover, without being assigned to do so, students formed a learning community that extended beyond the classroom in the forms of study groups, social gatherings, and online connections. We were delighted that many expressed the desire for more classes of this nature. "If there were more science classes taught this way (integrated) I would take one every year…. Too bad this will be my last science class, I really liked it."

The experience of teaching biology within the course combination compared to the stand-alone version for non-majors or even majors introductory biology was enlightening. We eschewed traditional exams and similar forms of assessment in favor of evaluating students by other means. For example, students demonstrated their understanding of mitosis and meiosis by explaining these processes to each other, and to us, using manipulatives. They were able to contextualize these biological concepts by connecting them to cancer and Down syndrome, respectively. For meiosis, students also incorporated their knowledge of this process in brochures they produced to inform families about Down syndrome. Student understanding of all biological concepts were evaluated by a combination of physical demonstrations, oral presentations, discussions, and writing. Refer to Table 2. Their understanding of the basic biological concepts exceeded what we have typically observed in the stand alone biology course. This degree of understanding was not unique to mitosis and meiosis; it was true for all of the concepts we explored.

Table 2. Example of Comparison between Traditional Biology Course and Blend Course

Traditional Standard Alone Biology Course	Outcome Products	Outcome Products Blended Biology and First Year Seminar Class
Meiosis	Quizzes and Exam	Oral exam with use of manipulatives
Mitosis	Quizzes and Exam	Oral exam with use of manipulatives
Genotype and Phenotype	Quizzes and Exam	Writing assignments (i.e., essays): -reflective essays -Analytical essays (informed by literature)
Inheritance	Quizzes and Exam	Informational brochure for parents who have children with Down syndrome Debate on the ethics of eugenics (past and present)
Chromosomes	Quizzes and Exam	Informational brochure for parents who have children with Down syndrome
Evolution	Quizzes and Exam	Debate on the ethics of eugenics (past and present)
Intentional Integration of Information	Not applicable	Debate informed by the literature and course content Analytical essays (informed by the literature)

Equally important, the laboratory component of the course was explicitly designed to emphasize the process of science. As the semester unfolded, students engaged in three guided independent research projects, the results of which they presented publically. Once again, the quality of this work was at least equal to if not better than what we have observed in the stand alone course. Because the format of the combined class was modelled on the scientific process, the lab and other components of the course reinforced one another with their continued insistence on clear articulation of questions, analysis, and evidence to support claims.

It is apparent that student learning was enhanced in this course in ways that were hoped for but not necessarily expected. Perhaps most significant, students' foundational approach and consideration of the primary question of the course, what does it mean to be human? shifted dramatically. They moved from quick reactive responses that were rooted in their personal experiences (as per formative assessments) to questioning, listening, and reading much more deeply. In confronting questions, students looked for mechanistic factors, social factors, and the interactions between the two.

We were utterly astonished with the maturation of thought and consideration of every student with regard to the primary question.

> "Throughout this course we have covered many of the ways in which we 'other' people… Indeed, learning about 'othering' and what we can do to prevent it, is very important… So, our running goal for this class, which will most likely remain our goal for our lives, is to continue on our journey toward inclusiveness."
> "This class made it abundantly clear for me that fearing heterogeneity is not wrong, but acting on this fear is wrong. Educating ourselves and each other on the importance of variation is what will allow us to escape the cycle of othering and marginalization."
> "I appreciated this class for it has started a discussion about differences. It acknowledges that we see them and it is okay to talk about those differences and continue to talk about them. It is talking which gets rid of the biases."

It is evident that over the course of the semester, students moved to a more sophisticated and nuanced consideration of

our big question.

Faculty

While we anticipated that students would be engaged in the course due to the nature of the topics, we were nevertheless surprised by the depth of their engagement. A partial explanation is that we discussed and modeled how we prepared for each class (e.g., article analysis, notes, conversations, time engaged with preparation); in short order the students' preparation reflected ours (e.g., annotations on the readings, notes from videos, study groups). In addition, we were surprised about the impact of our discourse with one another during class, on the quality of student discussion. A possible explanation for this outcome is that we modeled how to question each other, and at times, disagree respectfully and in fact, cheerfully; students took it in and were able to do so with each other as well. Given that the students were not science majors and in some cases, science averse, we were both pleasantly surprised at their curiosity and enthusiasm for the biological concepts and laboratory work.

Another positive consequence of the work has been the enlivening of our understandings of our own fields in the context of other bodies of knowledge and ways of knowing. As full professors, it has been exhilarating to share resources across fields of study, to engage in thoughtful conversations about the topics, and to challenge what each of us thought that we once knew or understood.

Doyle was specifically surprised by the impact of introducing the biological concepts via narrative. The students read and discussed the stories of the lived experiences of individuals which compelled them to ask "Why?" They wanted to understand the biology of each case. They used the scientific process to unearth empirical information to answer their questions. In its broadest manifestation, students used this approach tenaciously to answer the foundational question of the course: What does it mean to be human?

Bozzone's big surprise was the influence of this course on her other biology courses. In addition to learning new pedagogical approaches and techniques, she became more adept in using new language that sharpened her focus on topics she had taught for many years namely, othering, variation, and the concept of normal. More specifically, her perspective with respect to social science elements was enhanced significantly as evidenced by comments, discussion, and writing done by students in her other courses.

Conclusion

Our approach to opening the doors between seemingly discrete bodies of knowledge is not limited to biology and social science. It can be adapted to many fields of study. For example, one could imagine a religious studies course and a history course combined to examine causes of war and peace, or mathematics and music connected to explore the practical aspects and aesthetic beauty of patterns, or sociology and economics integrated to examine poverty within specific communities with the goal of identifying potential solutions.

We focused on biology and social science because of our individual areas of expertise. One of the challenges in trying to foster an understanding and appreciation of the importance of biology is that our educational system tends to compartmentalize science rather than seeing it as a central aspect of the liberal arts. In reality, the integration of knowledge—not simply within biology, but also among sciences, social sciences, humanities, and the arts—is essential for confronting and finding solutions to the challenges we all face. Our graduates ultimately have the potential to play important roles in meeting these challenges and helping to find solutions precisely because their particular interests allow them to see biology and science from different perspectives (Bozzone and Green 2014). Biology in particular, and science in general, represent one way of asking questions and evaluating the answers; it is not the only one. Still, the specific manner in which scientists engage in learning about the natural world is both powerful and successful. And as one way of thinking, it is practical for many questions, not just scientific ones.

Looking forward, we decided that rather than acting as if students will recognize the interrelatedness of knowledge spontaneously, we will commit ourselves to teaching with an intentional focus on intellectual connections. In doing so, we predict that students will broaden their views and see that knowledge is not so discrete after all. In fact, knowledge is all one big picture, one glorious tapestry, no matter how closely we may examine the individual threads.

Works Cited

Bozzone, D.M. & Green, D.S. (2014). *Biology for the informed citizen*. Oxford University Press, New York.

Brizbee, A. (2010). *Reverse outlining: An exercise for taking notes and revising your work*. Retrieved from https://owl.english.purdue.edu/owl/resource/689/1/

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

Knight, J.K. & Smith, M.K. (2010). *Different but equal? How nonmajors and majors approach and learn genetics*. CBE Life Sci. Educ. 9(1): 34-44.

Levy, A. (2009). *Either/Or: Sports, sex, and the case of Caster Semenya*. *The New Yorker*. 11/30/2009.

Sundberg, M.D. & Dini, M.L. (1993). *Science majors vs non-majors: Is there a difference? Journal of College Science Teaching*. 22: 299-304.

Tosun, Tarik. (2000). *The beliefs of preservice elementary teachers toward science and science teaching*. *School Science and Mathematics* 100(7): 374-379.

Wright, Robin L. (2005). *Undergraduate biology course for nonscientists: Toward a lived curriculum*. *Cell Biol. Educ*. 4:189-196.