INTRODUCTION

Despite advances in technology, science, and medicine, STEM (science, technology, engineering, and mathematics) communities still face issues of pressing concern that will require solutions that are only possible when interdisciplinary and diverse approaches are considered. Evidence indicates that diverse teams perform better than less diverse teams with higher abilities in complex task challenges, the very kinds of complex tasks that scientists now face (20, 22, 35). Despite this knowledge, diversity in STEM continues to be a pressing issue. Blacks and Hispanics make up only 7% and 6%, respectively, of the overall STEM workforce, whereas women are underrepresented in non-health care STEM fields, representing only 25% of the computer science and 14% of the engineering workforce (15). Extensive research has examined the many and complex reasons for the lack of diversity in STEM (8, 12–14, 19, 20, 42), and, as a result, many prominent national organizations have stepped forward as advocates for educational change. For example, the National Science Foundation, National Institutes of Health, and the Howard Hughes Medical Institute (https://www.hhmi.org/science-education/programs/inclusive-excellence) have invested in various initiatives to address diversity challenges in sciences. These organizations have specifically focused on increasing participation of students of color along with gender diversity in the STEM fields (18, 24, 34).

Many institutions have been actively examining their approaches to increasing diversity and inclusion on their campuses (10, 26). One common and comprehensive inclusive approach to help all students find success is culturally responsive/relevant teaching (CRT) (4, 17, 29). CRT was first described in 1994 by Gloria Ladson-Billings, an education researcher, to mean, “a pedagogy that empowers students intellectually, socially, emotionally, and politically by using cultural referents to impart knowledge, skills, and attitudes” (29). Characteristics of CRT may include, but not be limited to valuing and validating students’ backgrounds, using those differences as a strength in group work, using student-centered teaching strategies that allow for all students to be heard, or using diverse curricular materials and/or examples that reflect the backgrounds of your students.

In the sciences, an article by Tanner (40) suggested an inclusive and diverse set of pedagogical techniques or “equitable teaching strategies” that are grounded in research on learning. These inclusive teaching practices foster a sense of open communication among all students that is inviting and welcoming to learners from all backgrounds (23, 25, 26, 37, 43). These types of learning environments encourage collaboration between teachers and students to create and sustain environments in which students feel supported as individual learners and are encouraged to express their views and concerns (7). Implementing these ideas are not without challenges, as many STEM educators have had no formal training or exposure to CRT (10, 25). Faculty members may feel that they do not know where to begin considering students’ diverse family heritages, learning styles, and social identities in their teaching; 2) are not sure of how to incorporate culturally relevant examples in class; or 3) as scientists, do not have the expertise in nonscience topics and thus do not feel comfortable discussing them in a classroom. To help ameliorate these concerns, Dewsbury and Brame (10) published a comprehensive interactive online guide (https://lse.ascb.org/evidence-based-teaching-guides/inclusive-teaching) that outlines inclusive teaching practices from a broader perspective.

Another CRT approach suggests examining the curriculum. In STEM education, Handlesman et al. (20) noted, in Scientific Teaching, that many engineering programs “offer courses and experiences that teach students aspects of global diversity and inclusivity that will positively affect their abilities as engineers”. However, they also noted that, from a curricular standpoint, the physical and life sciences have been less systematic or universally focused on diversity issues (20). Across a variety of nonscience disciplines, when culturally relevant curricula, examples, teaching, and testing methods are introduced, a broader population of students has shown persistence in a variety of fields (1). In STEM, utilizing culturally relevant examples and experiences in science classrooms helps connect and motivate diverse students to positively affect continued success and performance in those disciplines (26, 32, 37–40).

Employing CRT and equitable teaching strategies in STEM classrooms can support student success, but it can also be a very important method for helping STEM students learn early on in their academic careers about the intersectionality of science and sociocultural issues. This point emphasizes the fact that many STEM students enter college with little to no knowledge of the way in which science integrates with broader and more diverse questions of human experience. These students often experience their science courses as discrete experiences that do not integrate with nonscience courses that have historically been the venue for critical examination of socio-
cultural issues. Because of the role that culture plays in health outcomes, the American Medical Association (2) has weighed in on the importance of integration of cultural knowledge into the curriculum and not as “add ons” outside of the traditional courses (https://www.aamc.org/system/files/c/2/54338-culturalcomp.pdf).

For many promising health-care focused students, human anatomy and physiology courses are often the first human biology-focused experiences for undergraduate students. Given the fact that many clinical graduate health care programs are now revising curricula to include cultural competencies, it is important that the next generation of students entering the health professions recognize that learning the scientific facts may not be sufficient. Today’s health care professionals should understand how health, wellness, and disease are influenced by culture, intersectional, and social identities.

In our experiences, when we have intentionally used examples of human biology where ethnic, geographic, and gender differences exist, we notice that students are more likely to stay after class to ask deeper questions, confirming that our students found relevance in what we were doing. Yet our approaches were borne out of our own curiosities and interests but were not comprehensive in scope. Therefore, we initiated this project with an overarching goal to be more systematic and comprehensive in finding and using culturally relevant examples from the human biology literature with the intent of updating our courses and sharing with our colleagues. This article summarizes the experiences and observations of the project with our students using an undergraduate research experience to identify culturally relevant examples in human biology.

What We Did and Why

The goal of this educational project was to find diverse and culturally relevant anatomical and physiological examples we could incorporate into our traditional human biology learning material typically found in a two-semester integrated anatomy and physiology course. To achieve our goal, and to involve students, we utilized two (of 10) evidenced-based, high-impact teaching practices that promote student learning, recognized by the American Association of Colleges and Universities (28). Therefore, we designed our experiences around undergraduate research and diversity/global learning. We also wanted to partner with our own science students as we embarked on this change project for two reasons. First, we wanted to help students integrate their knowledge of the human body while simultaneously giving them the opportunity to connect science to other fields of study from public health to geography to history. Second, while we found many of the examples interesting, it was essential for us to get the students’ perspective as learners, particularly what they found interesting/uninteresting and how what we discovered would be helpful and or interesting for other students. The main outcome of our original project was the creation of culturally relevant examples that will help us begin transformation of our anatomy and physiology course to a more diverse and inclusive experience for our students.

We created two separate, semester-long undergraduate research courses taught independently by the authors of this paper. Each research course consisted of three undergraduate students who had completed the anatomy and physiology courses, and each course included at least one underrepresented minority student researcher. Students were selected based on their interest in getting involved in the undergraduate research project. The course taught by J.D.V.H. focused on identifying culturally relevant examples in systems of the body that included, but were not limited to, integument, bone, nervous, muscle, and endocrine systems of the body. The parallel course taught by T.G.F. focused on the cardiovascular, respiratory, renal, digestive, and reproductive systems. These divisions closely followed the systems taught in our two-semester anatomy and physiology course sequence. During the first week, faculty guided the students on how to search databases for relevant references and discussed the various “lenses,” such as gender, geography, ethnicity, and/or socioeconomic status. Each research group met weekly and independently. The faculty facilitated group discussions and worked with students to determine whether specific references would be of value to the project. Twice throughout the semester, the two research groups (faculty and students) enjoyed joint discussions to highlight the best examples and share experiences. Students were required to attend the weekly group meetings and locate, analyze, and summarize relevant references that could lead to creation of new material. They also wrote an end-of-year annotated research paper, highlighting the best example of references and detailing their experiences and learnings in the course.

What We Learned

Originally, we had intended to use this undergraduate research experience to create a more comprehensive list of resources and culturally relevant examples that we and our colleagues could use in our courses. However, immediately after we began the project, we noticed two things. First, compiling any kind of comprehensive well-vetted reference list would take longer than a single semester. Second, and more importantly, we saw in our students a different kind of motivation to find, learn, and connect material in ways we had not observed from teaching the standard anatomy and physiology curriculum. As a result, our focus turned from our original intention of creating new teaching resources for faculty to characterizing and understanding the unique kinds of learning we were observing in our students. This change in focus gave us the opportunity to observe our students and their progress in such a way that we would not have been able to, if the only goal was to create a reference list. Rather, our observations of our students’ progress gave us the opportunity to better understand their learning process within the context of expanding our curriculum to include a focus on cultural relevance. What is reported here is from our observations of our students over the semester.

As students took charge of their learning, we took on a role that was more in line with a teacher-guide, one that progressed in step with the students’ learning process and offered guidance, advice, and possible choices for students. In this way, we were simultaneously managing the inherent power dynamic that is present in all classrooms by shifting more of the power to students to explore their own learning goals. Through specific weekly assignments, primarily literature readings in a variety of disciplines, and group discussions with fellow students and faculty, students were invited to connect and apply
their knowledge of human biology to a broader and more complex perspective. Moreover, students were required to go beyond their comfort zone of science and look for ways in which science connects with other disciplines. This aspect of the course meant students were reading references that forced them to move beyond the concepts taught in an undergraduate course in human anatomy and physiology. For example, when students searched for appropriate references for the integrumentary system, they quickly realized that, to create culturally relevant and diverse curricula, they would have to read material from nonscience journals. Thus, this undergraduate research experience became a place where students could bring together what they knew about the science topic and integrate that with other disciplines. Even a simply designed research experience can yield interesting and unintended positive learning outcomes for students and faculty.

For us, we were reminded in very poignant ways that students, too often, mistake material presented in the textbooks as immutable and equally applicable across all populations. Early on in our readings with students, they wondered why all of the interesting things they were reading and discussing were absent from textbooks. They argued that more undergraduate students should know about how various factors impact physiological adaptations and health outcomes. This demonstrated to us that our students had advanced in their cognitive understanding of how science is integrally related to broader and deeper societal challenges. Below are a few examples of themes uncovered over the course of the class.

**Human health care and disease can be complicated.** Students quickly and astutely noted that factors such as ancestry, socioeconomic status, or sex were critical in determining health outcomes often ignored in textbooks. For example, they noticed that African Americans had a much higher rate of end-stage renal failure than whites, independent of socioeconomic status (36). Or from a sex standpoint, they discovered that cardiovascular disease develops 7–10 yr earlier in men than in women, but is still a major cause of death in women (31). Students recognized that biological factors interact with cultural and environmental factors in ways that do not easily predict understood outcomes. For example, they identified one journal article reporting that Puerto Ricans have a higher prevalence of asthma than other Latino ethnic groups, even when they all lived in the same apartment complex (30).

Often overlooked by textbooks and traditional physiology journals, but often prevalent in public health journals, was the significant role that socioeconomic status plays in disease onset and progression. The students uncovered a study that found higher rates of hypertension, a major risk factor for atherosclerosis, among those of a lower socioeconomic status primarily due to lifestyle choices (3). The study also noted that populations from a lower socioeconomic status also had higher mortality rates from atherosclerosis because they lacked access to quality health care, which sped up disease progression.

Students began to understand that socioeconomic status significantly impacts access to medical care and early treatment. In addition, but not always prevalent, were the impacts that diet, lifestyle choices, and living conditions had on disease progression. Since the majority of our students are interested in the health care and biomedical fields, this was a key and important insight for them to discover.

**Approach diversity with caution.** One challenge in this assignment was that most of the literature our students identified described contributory and interactive factors that impact health outcomes with mostly and frequently negative consequences. Therefore, we wanted students to find “diversity” factors that yielded positive or protective health outcomes. For example, they found one example where individuals from countries where fish consumption is high, such as Japan and Greenland, often have lower rates of cardiovascular disease (21, 27). In addition, they discovered an article that found Muslim women have much lower rates of cervical cancer compared with non-Muslim women, which led to important discussions with students about religious beliefs and views on sexual activity, as well as the data regarding the increased risk for cervical cancer with multiple sexual partners (44).

This latter example gave us pause and acutely highlighted the particular challenges or unintended consequences this assignment may create. Presenting research on some topics might unintentionally create or reinforce stereotypes of those particular populations. In this particular case, a student presented on the cervical cancer topic in a class that had a Muslim student present, it would likely lead to a less inviting or inclusive classroom. Thus we urge caution on topics that students choose to examine, and that faculty know ahead of time how to approach these discussions with inclusion and equity as the goal. This example also highlights how faculty knowledge of religion, sociology, anthropology, history, and minority populations would be essential to contextualize many topics in class (see recommendations for parameter setting around such topics). This is a challenge for many science faculty members, as their typical graduate-level training and postdoctoral experiences likely lacked ideas or strategies about how and when to incorporate these areas of knowledge.

**Making connections to other disciplines.** During our course, it was apparent that students were deepening their knowledge of physiology, as they were engaged in the scholarly activity of searching for and reading primary literature. For example, in one of their discoveries, students found an article that showed Chinese women with a high dietary soy consumption do not experience the extreme effects of menopause compared with women with lower soy intake (45). In digging through the explanatory mechanisms, they correctly outlined the process of how soy, which contains phytoestrogens, may mimic the activity of the hormone estrogen in your body. When the study put Chinese women on controlled high-soy intake or low-soy intake diets, they found the women who ate the high-soy diet had significantly lower endogenous levels of E1 and E2, two types of estrogens, compared with those on the low-soy diet. In this case, high-soy intake leading to lower estrogen levels may help explain why Chinese women experienced more modest menopause symptoms. In almost every paper, the students had to refer back to their textbook and/or other primary references to either learn the basic anatomical/physiological concepts or refresh knowledge based on their original coursework. Thus we were pleased to see them making new connections and expanding knowledge of human biology beyond the material presented in the textbook.

Students also delved into how to incorporate culturally relevant examples into the curriculum. While focusing on the integrumentary system, the students suggested researching the importance of skin color in cultural acceptance. They came
across examples that challenged their assumptions on skin color and racism. For example, in one study about albinism in Kiolo, Tanzania, researchers found that marginalization of the affected child depended on whether or not there were other members of the family similarly affected. They also learned that discrimination was not always clear, but was often linked to social hierarchies and economic/political power. In contrast, however, religion sometimes viewed albinism in a positive light (5). In another example, students researched the effectiveness of mindfulness in pain management, finding not only that it is an effective strategy for reducing pain, but that mindfulness is important for everyone, regardless of whether or not he or she experiences pain (33). This experience led them to study the effectiveness of meditation, the history of meditation in Asian cultures, and the perceived lack of a cultural norm in the U.S. for quiet, meditative moments.

In many cases, students started off believing that they were asking a very specific anatomical/physiological question (e.g., mindfulness and meditation) and, by digging through the research, realized that the answer to their question could be viewed from a variety of lenses, with more complexity than they anticipated. In a final example, this became salient to students when they examined bone growth and how external forces can shape and reshape bones. This led them to deep questions about the utilization of specific methods used in different cultures to shape bones into what was “historically” culturally acceptable (such as foot-binding, or long boards). They then were able to tie this practice to the current rise in positional plagiocephaly (unintentional skull deformation in infants) in the United States. All of these examples taught students that anatomical and physiological knowledge is more than knowing just the facts: it requires placing these facts into context, in time, place, and culture.

From our observations, we noted four overwhelmingly positive outcomes:

1. All of the students reported a deeper and more complex understanding of how intersections of ancestry, culture, language, and socioeconomic status can impact health, something that is critically important, as they all intended to pursue careers in health care.

2. Examining science literature through a diversity lens provided students with a way to examine a topic often reserved for nonscience courses. Students found this to be a very rewarding and unique opportunity to experience their worlds coming together.

3. We noticed a significant improvement in both their information literacy and critical reading skills. As the semester continued, the students noted an ability to probe for and find key resources using multiple search strategies that required finding references that were sometimes outside of the general science databases. They also were able to quickly distinguish between primary and secondary literature and, when it was necessary, dig back into the primary literature to more fully understand how the research was conducted to assess the quality and applicability of the research findings.

4. Student-faculty interactions and weekly discussions were key in helping develop students’ capacity to understand how to examine science with a diversity and cultural lens, ultimately realizing during the course that we know about human biology and health is limited only by the inclusiveness of the questions we ask.

**Recommendations**

We intentionally engaged our students in a semester-long research project to fully assess the assignment’s capacity to get students to think more critically about science in the context of a diverse set of factors. We learned as much as our students did, including identifying areas of our own teaching where we might need additional training and experience. That said, we believe that a shorter course-embedded assignment for students can profitably be added to either a lecture or laboratory course with some due caution. As such, we offer the following recommendations and parameters for implementing this as an assignment into an existing course.

1. Be intentional and transparent. Make sure students are aware of the reasons you are asking them to conduct this type of research and how it might impact their learning and career.

2. Give students specific prompts that include both a system (bone, reproductive, etc.) and a critical lens, such as gender, ethnicity, socioeconomic status, ancestry, or culture to help focus their research. For more extensive systems, such as the cardiovascular or digestive systems, the system can be broken down into smaller more manageable segments. Limiting those critical lenses to those areas where you are most comfortable and/or have particular expertise reduces the chance of having some research be misinterpreted or the potential to single out and/or stereotype a particular group. You might limit the lenses to choices made by groups, such as diet, exercise, stress, mindfulness, or geographic region. Having students seek instructor approval on topics of interest before searching may help avoid any challenging situations.

3. This assignment also represents a good opportunity to discuss “race.” First, it is important to either educate and reinforce for students that “race” or “racial” are not biologically based, but are referring to social constructs often used to categorize or count different populations, such as in a census (41). Moreover, these same constructs are often based on classifications of observable physical features, with skin color being the most prominent. In fact, there is a movement away from using the race or racial concept in biological research, arguing that race is too crude of a construct to be used effectively as a useful search parameter and has conflicting social meaning, both of which interfere with a more scientific approach and understanding of human genetic diversity (16). Second, if you are comfortable, this might also be an appropriate time to discuss structural racism that leads to health care disparities for people of color (11). With regard to search strategies, many scientific journals use more historical categorizations of “race” in determining health disparities or disease progressions. Using ancestry or geographical regions as a lens might be more helpful and less controversial in search strategies. For example, examining the physiology and adaptation of “highlander” populations in Tibet and the Andes may provide a more useful approach and provide an additional example of a positive adaptive response (3a).
4. Inform students that they will need to search for material in databases besides Medline, and that they should take this opportunity to work with a reference librarian for assistance. They may need to look for resources found typically within other disciplines, such as anthropology, history, and public health, and many science students are less familiar with databases in these areas or the types of journal typically found within them.

5. Include time during class for student presentations on the topic and prepare the others for a robust discussion about the critical issues. If you are uncomfortable at the outset with in-class presentations, perhaps a first step is to introduce the assignment as a written-only experience until you get a sense of the types of projects in which students are most keenly interested. Moreover, introducing this as a written assignment provides the opportunity to ask students to reflect on the value of the experience to their learning. As the instructor, you will have the option to share with the class any of the most relevant findings.

Ensuring that our science teaching is inclusive and supportive of diverse populations is the responsibility of every faculty member if we intend to reach STEM equity in higher education and in the workforce. We believe this assignment adds to a growing list of pedagogical strategies that can be utilized to make anatomy and physiology curriculum more relevant and inclusive to a growing and diversifying student population.

DISCLOSURES

No conflicts of interest, financial or otherwise, are declared by the authors.

AUTHOR CONTRIBUTIONS

T.G.F. and J.D.V.H. conceived and designed research; T.G.F. and J.D.V.H. analyzed data; T.G.F. and J.D.V.H. drafted manuscript; T.G.F. and J.D.V.H. edited and revised manuscript; T.G.F. and J.D.V.H. approved final version of manuscript.

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