Teaching Cancer Biology Through a Lens of Social Justice

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Abstract

The biology classroom is not separate from the greater context of society; social issues can and should be presented in connection with the content. Here we present an example of antiracist teaching using the molecular/cellular biology of cancer in an introductory biology course as a topic through which to address historic racial disparities. Through this lesson, students analyzed biological science through the lens of social justice, specifically looking at disparities of cancer incidence with ties to health outcomes and environmental racism. The synchronous activity begins with personal tie-ins to the broader subject of cancer and then dives into the molecular regulation involved in creating cancerous phenotypes. Cancer biology is explored using an active-learning style based in process-oriented guided inquiry learning (POGIL) tactics. Multiple levels of assessments pushed students to grapple with data about racial health disparities and make explicit connections between these data and molecular mechanisms of cancer formation. This paper provides activity worksheets, an activity timeline, an example of assessment items, and teacher preparation for other instructors who want to emulate this lesson either directly or as an example of adjusting other science topics towards this lens. For those teaching in different topics, we offer advice and examples to help instructors to include social justice lenses into their science teaching.

Learning Goals

Students will

- understand cancer as a collection of disease-causing syndromes related to group-action of mutations.
- explore the intersection of social justice and molecular biology through examples of racial impacts on cancer outcomes.

Learning Objectives

Students will be able to

- categorize a mutation as likely or unlikely to contribute to a cancerous phenotype.
- assess a set of related mutations within a single cell lineage and predict whether or not the organism is at risk for cancer.
- begin to express outcomes of scientific issues in terms of social justice impacts on various communities.

INTRODUCTION

Cancer is a fundamental topic in biology because of its significant impact on human life and because it spans a broad range of fundamental molecular and cellular processes (1). Despite having considerable impact on human life, there are large disparities on how cancer impacts different communities (2). The traditional model of college instruction typically introduces scientific concepts first and then applying these concepts to social needs later, if at all (3). We needed a lesson to teach cancer biology which prioritized the historical and systematic disparities regarding how this conceptual science has been applied or not for different peoples (4–6). While there are strong cancer-based lessons available (7, 8), the lesson described here uses in-class active learning about cancer cell models and then explicitly links that active learning to a deeper look at historic and unjust patterns of human contact with pollution across different racial groups. This unit is intended to be relatively short, highly engaging, and

Why Science Needs to Incorporate Social Justice

Traditionally, STEM is taught as an isolated topic that is separate from society; science is viewed as objective and therefore not related to the social issues that plague our country (3). However, we cannot deny the connection between biology and social issues any more than we can deny the connection between biology and chemistry. Whether it is the racist ideologies that influence how we conduct science (examples like the San Antonio Contraceptive Study (10) and Tuskegee (11)) or the structural inequalities that
influence biological processes resulting in poor health (examples like the New York North River Sewage Treatment Plant (12) or the Flint Water Crisis (13)), race and social justice are intertwined within the field of biology.

By ignoring the intersectional role of social justice, future scientists and citizens of this country are doomed to repeat the injustices of the past; our future scientists will continue to lack the social consciousness that could have prevented the San Antonio Contraceptive Study and the mental framework to examine the biological impact of government policies (10, 14). As a result, marginalized communities will continue to be neglected and oppressed. To prevent the perpetuation of this reality, we must incorporate social justice within the STEM curriculum. By addressing injustice in the classroom, we hope our students move one step closer to becoming informed individuals ready to address injustice outside of the classroom.

Of course, this one lesson will not be enough to dub our students as experts in social justice, just as one introductory biology course does not dub students as expert in biology. We weave social inequalities into this lesson to explicitly place the importance of examining biology through the lens of social justice. Students begin framing biological outcomes within the context of societal structure; developing this framework is key to understanding how inequalities intersect with biology and other STEM disciplines. We cannot wait until someone has developed a full curriculum of social justice STEM education. Rather, we must act now and implement lessons such as this one to begin the development of socially conscious scientists.

**Intended Audience**

This lesson is designed for students in introductory or mid-curriculum courses in molecular biology. The population with which this has been tested were first-year students at a large research university, of whom most went on to majors in science.

**Required Learning Time**

This lesson requires 50 minutes of teaching time for an in-class activity as well as a multi-item segment of a following summative assessment. Instructors should expect the social justice implicit to this lesson to generate extra discussion outside of formal learning times.

**Prerequisite Student Knowledge**

Students should understand topics pertaining to cells, DNA, proteins, genetic regulation and tissues at the Introductory college level. Generally, this means this topic is a good fit in the second half of whichever Intro course covers the typical molecular and cellular topics.

**Prerequisite Teacher Knowledge**

To facilitate this lesson expertly, teachers should be familiar with institutional racism (15–17), environmental racism (18, 19), the history of redlining (20, 21), and the genetics of race (22, 23). Even without being an expert in the history of racism, teachers can effectively facilitate this lesson by creating a safe space to facilitate complex discussions (24, 25). The practice of setting classroom norms and community agreements is well-described and can be very helpful (26).

Teachers cannot simply lecture about social justice (27). Through vulnerability and honesty, teachers must create an atmosphere that encourages students to engage in open dialogue.

Students must actively wrestle with social justice issues, not only for the sake of gaining knowledge, but to also develop a sense of empathy. For those who do not come from historically marginalized communities, this can be an uncomfortable discussion. Ultimately, teachers should be prepared to feel uncomfortable, especially White teachers. Students will only open themselves up to discomfort to the extent which teachers model this behavior. Willingness to sit with discomfort will dictate how much students take away from this lesson.

This lesson examines the connection between environmental factors and the rates of cancer. As students will see, exposure to environmental factors, which predisposes individuals to cancer, disproportionately impacts communities of color. To expertly facilitate this lesson, teachers should understand how institutional racism has operated in America and how environmental racism has negatively impacted marginalized communities. For greater context of how some marginalized neighborhoods have been formed, teachers should familiarize themselves with the history of redlining and white-flight.

A solid foundation in cellular and molecular biology is required to facilitate this activity. This includes understanding central dogma and the cell cycle. Building upon these concepts, teachers should recognize how disruption of these processes influence the development of cancer. Understanding the role of mutagens as they relate to proto-oncogenes and tumor suppressor genes will be critical when examining cancer through the lens of social justice.

We recognize that as it stands, most STEM instructors are not already equipped for these conversations. However, there are tools and strategies instructors can rely on, such as the “Let’s Talk: Discussing Race, Racism, and Other Difficult Topics With Students” (24), to successfully facilitate these difficult conversations. To achieve the justice-based teaching we want for our students, instructors should first honestly reflect on their understanding of social inequality and conduct their own research to fill in the gaps in their knowledge. Supplemental 1 (Supporting File S1: Teaching Cancer Biology Through a Lens of Social Justice – Glossary of Key Terms) provides instructors basic definitions of key ideas as well as links to additional resources to begin their learning. Second, instructors must model the behavior they hope to see from their students. Third, instructors should develop a plan to facilitate the conversation. Costello et al.’s “Let’s Talk” provides graphic organizers to create a plan to navigate strong emotions, harmful comments, and misinformation as well as strategies to create a safe space for open dialogue (24). Lastly, instructors must recognize that it is ok if they do not have all the answers. Social issues are complex. We do not expect other instructors to come to this lesson with all the answers. However, we expect instructors to be willing to grow and learn with their students as they facilitate these conversations.

Above all else, teachers must understand that race is a social construct. It is not because of race that people are at risk of cancer. It is because of unjust policies and institutional racism that extrinsically place communities of color at greater risk of cancer. If you are interested in more literature around this subject, a strong starting point would be through critical race theory (28–30).
SOCIAL JUSTICE TEACHING THEMES

Social justice encompasses four main themes: access, equity, rights, and participation (for critical discussion of these important concepts, please see (31–33).

1. Access: opportunity to basic necessities, such as quality education, healthcare, and housing, regardless of socioeconomic status.
2. Equity: proportionate distribution of support/goods/aid given the circumstances of each individual.
3. Rights: access to civil liberties and human rights regardless of social identity.
4. Participation: freedom to take part in the democratic process without barriers and equal power within the various institutions.

During the class activity, issues of social justice within marginalized communities are presented to students. On the actual high-stakes assessment, instructors should use a pre-released (aka ‘public’ (34)) exam to catalyze discussions. Preparing for this assessment requires students to specifically address issues of access, participation, and rights within Black communities. They examine the distribution of toxic waste sites among various communities and relate this data to the rates of cancer incidence. From the data, students will observe a higher distribution of toxic waste sites and higher incidences of cancer in Black communities. They should make a positive correlation between toxic waste sites and rates of cancer incidence. Next, students are asked to make a connection between Black people, cancer, and toxic waste sites, in which they discuss issues of economic limitations, housing policies, and institutional power.

It is important to note that while equity was not discussed in this lesson, it was not purposely left out. Social issues are complex and to address every aspect of an issue within one lesson may not be possible. Just as we cannot address every signaling pathway in one introductory biology course, we cannot address every aspect of social justice within this one lesson. However, by attempting to integrate social justice within the course, we initiate the necessary conversations to begin addressing injustice within our communities.

SCIENTIFIC TEACHING THEMES

Active Learning

Instructors measure learning on this topic in three ways: polling questions, pre- and post-testing via online survey questions, and an in-class written exam. In-class formative assessment through a set of interspersed polling questions help adjust instruction in real-time based on student progress and rates of correct responses. Pre- and post-testing on similar questions within the 24-hour window of the class activity should be completed using participation-only, online survey questions intended to understand and ultimately to reduce the gaps in achievement between student demographic groups. Summative assessment is done through a high-stakes exam in a public exam (34) format.

This class activity is designed to be highly active, with less than 15% of the class time being used for didactic or passive lecture (35). Students will engage in peer instruction (36), POGIL (37), polling questions (38), group discussion (39), hypothesis building (40) and data interpretation of models and figures (41). The assessment strategies tied to the in-class activity are intended to incentivize active and social studying strategies.

Assessment

Science curricula are densely packed with conceptual and factual material that must be covered to meet course goals, and social justice topics can add to the overstuffed that professors struggle with. Following the guidance of K-12 traditions of educative assessment (42), we found ways to include important issues of social justice into the curricula by blurring the divide between instruction and assessment. When done well, even summative assessments can and should be part of the learning structure of the course and not simply extractive mechanisms for assigning grades. The introduction and exploration of social justice themes presented here are introduced in direct instruction but then intentionally given more value and room for study through the use of assessment methods that catalyze discussion and critical thought before, during and after the activity. We present these strategies in response to well-intentioned teaching methods that allow social justice into the instruction but ultimately imply less value to these topics by keeping them out of the most impactful aspects of student success: the exams themselves. Placing heavy emphasis on social justice learning on the summative exam is intended both to assess student learning, encourage further investigation of social justice topics, and help to teach through a social justice lens, further described in depth below.

Inclusive Teaching

This lesson is designed to utilize best practices in active student engagement. The topics and material chosen were designed to address puzzling or challenging phenomena in students’ lives (43). Early in the activity, instructors create opportunities to explicitly think about a personal connection to this cancer biology in a way that values diverse backgrounds (44). This lesson ties traditional scientific understanding directly to issues of social justice in ways that are likely to benefit student success throughout their development (45). Alignment of teaching and assessment by awarding points on the exam communicates the moral and ethical value of social justice through STEM learning (46). The material is taught actively to help include students from traditionally underrepresented backgrounds and reduce the achievement gaps (47). This is done primarily through a POGIL structure (48). Course instructors and teaching staff strive to teach in a personable, caring way to create an atmosphere of learning that can help to break down historic barriers to access and retention for marginalized communities (49–51). Notes available to students before class made clear that topics of racial justice would be discussed, and we note that including this kind of language in course syllabi may help some students from historically marginalized communities reduce the anxiety associated with being a student of color at a predominantly White institution discussing social justice topics.

LESSON PLAN

The in-class activity component of this lesson is taught in a style known as Process-Oriented Guided Inquiry Learning (POGIL) (37, 48). In a POGIL, the instructor frames the lesson topics and relevance and then guides students through individual- or small-group-work towards a self-constructed
understanding of the content (more general information about POGIL is available at https://pogil.org/). This initial framing is supported by the provided timeline (Supporting File S2: Teaching Cancer Biology through a lens of Social Justice – Class Timeline); lecturer slides (Supporting File S4: Teaching Cancer Biology through a Lens of Social Justice – Class Slides with Polling Questions) and example video (Supporting File S3: Teaching Cancer Biology through a Lens of Social Justice – Video Example of the Class Session) and puts issues of personal experience and social issues explicitly on the table, which is important for conceptualizing the science of cancer through a social justice lens by the end of the activity and prior to assessment.

The POGIL activity is guided by a two-page worksheet (Supporting File S5: Teaching Cancer Biology through a lens of Social Justice – POGIL Student Worksheet and Key) that provides a stylized model of a healthy human cell and a similar cell that has accumulated mutations, which could lead to a cancerous phenotype. The worksheet provides leading questions that help students to interpret the models and then apply those new understandings to the larger science of cancer and carcinogens. Students work independently for short periods of time punctuated by check-in questions (Supporting File S2: Teaching Cancer Biology through a lens of Social Justice – Class Timeline) and short discussions; these help to ensure that all students are taking correct conclusions from the data in a timely fashion (in other words, to avoid ‘flailing’ due to incorrect assumptions, which can happen with longer inquiry-based activities). Instructors should expect to allow students to work for intervals of ~5 minutes at a time, then interrupt and poll students for answers. Polling is often done best in a Peer Instruction format (36) using reflection, self-response, discussion (39), and then re-response...but this is not necessary for all questions in POGILs in order to facilitate learning.

The instructor concludes the lesson with a small set of final questions and a post-activity wrap-up. Rooting the conceptual scientific work in social justice themes is started during the activity but maximized by introducing data on unjust social outcomes of cancer; the importance of social justice work is conveyed by including this work on summative assessments and grading students on their ability to make sense of social inequities by connecting their knowledge of molecular biology to cancer.

For courses with graduate Teaching Assistants or Peer Learning Facilitators: One discrete way to maximize teaching and learning of social justice in STEM is to provide the class materials to be used and opportunities for discussion among the teaching team prior to the class activity.

**ASSESSMENT**

The summative assessment for this class activity on cancer is tightly tied to the goal of initiating the development socially-conscious students; indeed, it uses the significance and importance of a high-stakes exam to emphasize the importance of social justice themes. Without this alignment, students may recognize that issues of social justice are important, but not important enough to be worth points. Utilizing the exam in this way helps to promote further learning, especially among students for whom past privilege has made learning these issues unnecessary.

Problem #1 on the exam (Supporting File S6: Teaching Cancer Biology through a Lens of Social Justice – Exam Question and Key) asks students to explain inequitable data patterns of cancer outcomes for people from disparate racial backgrounds (adapting Figure 1 into Supporting Files S7: Teaching Cancer Biology through a Lens of Social Justice – Exam Question Public pre-released version) in (52) and Figure 2 in (53). Much of this information is pre-released in a public exam format (Supporting File S6: Teaching Cancer Biology through a Lens of Social Justice – Exam Question and Key) to allow students to think deeply about the subject and the data prior to the exam date. Pre-release of exam topics helps to ensure students understand the value course instructors and staff placed on this topic. Preliminary research suggests that public exams help students more efficiently, to think more deeply, and to do so with less anxiety (Wiggins et al., 2021, in review). The combination of testimony (from a fictional political) and interrelated, corollary data is both authentic to future student careers and also problematically complex. Were this material shown to students only in the midst of a traditional ‘surprise’-style exam, it would be overwhelming and counterproductive. The pre-released information catalyzes and motivates the independent discussion, review and critical thought that is required for students to internalize complex concepts that combine science learning and the newly-introduced intersections with social justice. As discussed, the goal is not to create social justice experts but rather to put issues of social justice explicitly on the table for examination within a science framework that has been traditionally kept artificially separate. This links large-scale learning about population outcomes to the molecular ramifications of living in closer proximity to mutagenic and carcinogenic waste due to historical injustices. Students analyze the statement of a fictional politician espousing anti-scientific lies. For credit, students must challenge a subset of those statements using molecular and/or cellular reasoning. Because each student does not need to address all of the false statements, for reasons of time and length, they are able to learn more from the exam key later.

Sadly, the expression of anti-scientific and biased lies from authority figures has only increased since our implementation of this lesson in 2019, underscoring the importance of antiracism in STEM.

**TEACHING DISCUSSION**

The goal of this activity was to conduct science education through the lens of social justice in such a way that students actively engaged with social justice topics without sacrificing the level of science competency students typically gained from this course. We attempted to accomplish this by having students analyze data related to cancer rates among different racial demographics and distribution of toxic waste sites in various communities. The data was pre-released to students in the form of a pre-released public exam prior to the exam date. After pre-release of the data, we observed strong student engagement with question #1, Fig. 1 and Fig. 2. Within and around the class, we observed students engaging in discussions spanning a wide range of concepts from the history of redlining and environmental racism to free-radical induced mutations and proto-oncogenes.

This teaching strategy translated into encouragingly high rates of correct student responses on social justice related questions (>75% correct, which compared favorably to the rest of the
exam). Students made valid connections between race, cancer, and toxic waste sites, in which they addressed institutional factors that led to the observed data. While this is not proof of deep learning or expertise in social justice, it helps to indicate that conversations are opening within a STEM environment in which these topics had previously not been addressed.

This teaching strategy showed evidence of significant and consistently learning of molecular/cellular science concepts. Student learning in the area of molecular/cellular biology was assessed using pre- and post-testing on high-level cognitive questions shortly before and after the in-class activity in a previous publication (54). Analyzing a set of 8 questions, we observed that comprehension was significant on challenging conceptual items, there were no differences between demographic groups, and understanding was consistently strong compared to other teaching methods used with a control group for which social justice themes were not addressed. For those interested, this analysis is described in depth on pages 8-9 of Wiggins et al (2017), in which ‘CellCycle’ was the title for this activity. From this data, we conclude with some confidence that teaching through the lens of social justice did not deter learning of molecular/cellular topics. Using this lesson, students were provided an opportunity to expand their perspective on social issues and begin developing a socially conscious lens while simultaneously improving their understanding of the biological concepts within the topic of cancer.

Successful implementation of this lesson was guided by a few key aspects in our approach: dedicated class time for discussion, use of active learning strategies, and placing equal value on social justice themes.

Carving out space within the classroom was a critical component in this activity. Social issues can be an uncomfortable topic to discuss; this discomfort stems from vulnerability. These conversations ask us to be vulnerable enough to question our own perspective and attempt to sit with another individual’s reality and confront our own privilege, potentially invoking feelings of guilt, shame, grief, and even denial. Be mindful of these emotions and take breaks as needed, but do not let fragility (White, male, cisgender, etc.) obstruct the conversation. The purpose of addressing social issues is not to place blame. It is to understand the context of the system in which we are in and understand how we benefit, perpetuate, and/or are affected by systemic injustice, depending on our respective identities. Students may get defensive as the conversation progresses. Make use of probing questions to de-escalate a defensive stance. Encourage students to explain their beliefs and allow for alternative ideas to be presented by you or other students. Our role as instructors in this dialogue is to provide structure for students to discuss ideas and their lived experiences without making space for intolerance or misinformation (See “Let’s Talk” by Costello et al. for guidance on facilitation strategies (24)). Without intentionally setting aside time for these conversations in the classroom, they may not occur at all. By engaging in open dialogue in the opening of the activity, the peer discussion of questions, and the pre-exam studying moments we gave students opportunities to break down the stigma of discussing controversial topics. In conjunction with other active learning strategies, Introductory Biology students in this course began wrestling with complex ideas of social justice.

Active learning strategies allowed students to create their own authentic understanding of the world rather than simply accepting being told how to view science through a social justice lens. It isn’t enough to inform students that injustice is rooted within our society (27). For them to become socially conscious scientists, they must arrive at these conclusions on their own and awaken their own consciousness. Active learning tools such as POGILS and polling questions increase student learning of scientific concepts, but they also go further. Students can approach complex data with no single clear interpretation, which is authentic to the kinds of critical problems we expect to be preparing them for. Data relevant to social justice is not only often incomplete, these communities that are the most impacted are often simultaneously the least well-studied so that simple causal relationships are not clear. These socio-constructivist strategies provide a framework for students to construct their own meaning from social aspects of the content. Furthermore, shifting from didactic lecture on racial disparities and cancer to an active lesson with a well-aligned summative assessment reinforced the importance of social justice. This lesson provided students the opportunity to earn credit on an assessment by discussing social justice themes as they relate to biology. Our decision to directly link course points to understanding the biological implications of racial injustice iterated that social issues are not just buzzwords that we chose to highlight, but rather that they are complex issues that influence all disciplines and deserve our full attention.

The in-class activity provided opportunities for tying the topics of social justice to the content of a STEM course. Future iterations of this lesson could be strengthened and facilitated by polling questions on social justice topics earlier in the course. We hope that future instructors will adapt this work to align well with the degree to which social justice thought is made explicit in prior class sessions. Additionally, the cancer lesson was presented relatively late in the term. Using a similar activity-plus-aligned-assessment style for a topic earlier in the quarter might better catalyze social justice themes across the course.

The traditional model of science education lacks the social context necessary to mold socially conscious scientists. We attempted to address this issue by expanding cancer biology from the confines of the classroom and into the greater societal context. This lesson serves as an introduction on how to create a social justice-based lesson within STEM education. We encourage others to use this framework to create additional lessons; anecdotally it sparked the kind of questions, conversations, and growth that we want to see in our students, which we believe in turn will make for more ethical, inclusive, and productive science in the future. Even if you decide not to incorporate this specific lesson into your curriculum, we hope that this provides guidance on developing your own lessons through the lens of social justice. One lesson at a time, we reconstruct a curriculum rooted in social justice, bringing us one step closer to a just society.

SUPPORTING MATERIALS

• Supporting File S1: Teaching Cancer Biology through a Lens of Social Justice – Glossary of Key Terms
• Supporting File S2: Teaching Cancer Biology through a Lens of Social Justice – Class Timeline
• Supporting File S3: Teaching Cancer Biology through
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