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Creating An Equity Based Genetics Unit Using Culturally Relevant Pedagogy And The Next Generation Science Standards

Katherine Quattrini

CREATING AN EQUITY BASED GENETICS UNIT USING CULTURALLY RELEVANT PEDAGOGY AND THE NEXT GENERATION SCIENCE STANDARDS

By

Katherine G. Quattrini

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Capstone Project Facilitator: Jana Lo Bello Miller
Content Expert: Sarah Hick

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CHAPTER ONE

Introduction

Overview

While there has been legislation prohibiting segregation and discrimination based on race, there have been few federal discussions about the institutional racism that minority students face today. Deep-rooted biases, ignorance and low expectations plague American schools and many BIPOC (Black, Indiginous Peoples of Color) students are deprived of their right to a fair and equitable science education. Schools were created with an emphasis on Whiteness, and the standards, curriculum, and traditional science teaching methods of today reflect that. While there is no quick fix, as educators and allies we must take progressive steps toward ending this institutional racism and bias that lead to the belief that BIPOC students cannot achieve the same levels of success in science as their White peers. Most importantly, we must work toward closing opportunity gaps to ensure that each student is given the best chance possible to succeed in our schools, regardless of cultural, ethnic, or socioeconomic identity. For this project, I will be exploring the question: *How can science educators create a more equitable science classroom in order to increase engagement among BIPOC students?*

My Time as a Student

Growing up as a White student in an affluent school district, I was admittedly ignorant about the prevalence of racism in schools. I believed that overt racism ended with the Civil Rights Movement and it definitely wasn't something that was tolerated in most American schools. What I didn't realize (and what I believe many other White Americans still don't realize) is that there is a stark difference between overt racism and covert institutional racism. I didn’t notice the institutional racism because I was benefiting from it. I had the privilege of not having to think about my race because my race was not the first thing that anyone noticed about me. There was one Black student in my high school, and the peers and teachers I was surrounded by were entirely like me: White and privileged. I was unaware at the time of how much this was actually shaping the way that I looked at the world and the way that I subconsciously looked at people who were different from me. When I got to college, it was more of the same. Surrounded by predominantly White, privileged classmates, my horizons remained unbroadened and I stayed comfortably within my bubble of ignorance. It wasn’t until I found my way to Hamline that I started realizing that the way I grew up, who I surrounded myself with, and my own racial identity was not a coincidence. I started asking myself: Why were there no students of color in my high school? Why didn’t I have any friends who identify as BIPOC? Sure, I knew that I wasn’t a person to look down upon someone who was different racially, but I started to realize that that is exactly what happens. Those who are not White are looked down upon – because White people have the ability to “look down”. We see ourselves as the default, the normal upon which others can deviate from and be abnormal. This is the premise upon which this country was founded and upon which all of our institutions were built. My Education and Diversity course at Hamline opened my eyes to what BIPOC students are facing today and why these students are perceived to be underachieving – because that is exactly what the public school system was built to look like. Whether I like it or not, as a White educator I enter my classroom with a set of biases that have been indirectly ingrained in me through the life I have lived and the systems that I have benefitted from. I feel a deep need to disrupt that system and ensure that each BIPOC student who enters my classroom leaves feeling supported by me and by the system and that each White student who enters my classroom does not leave having had the same comfortably ignorant experience that I did. My passion doesn't come from the will to save or to be a savior, as these students do not need saving. These students need support and encouragement, and to know that they are every bit as capable as their White peers at achieving greatness, despite the hurdles and inequities that they have been presented with through no fault of their own. As a White educator, I want to be an ally and continually be learning how to make the school system better for all students. I want to know culturally responsive ways to teach science and start making science education more equitable for BIPOC students. I want to bring more awareness to White students about what it means to be White in this country and how that can be used to fight the systemic inequalities that their peers face on a daily basis. I believe that this can be done by modifying instruction using the Next Generation Science Standards to be more inclusive and by creating a classroom environment created through the lens of culturally relevant pedagogy, and this unit is where I plan to start.

My relationship with science throughout school was much like most of my peers – it was a means to an end, a required credit earned toward graduation. I was "good" at science because I was good at making flashcards, memorizing terms, and drawing and labeling pictures. Labs were explicitly written out for us, with the question, hypothesis, and desired outcome discussed beforehand. There was no exploration, no problem solving, no inquiry. We just did what we were told because our teacher told us to do it. Did I retain any of that information? No. Was I able to make connections between concepts or units? No. So while I enjoyed science, I now recognize that I was good at it because I was good at school, good at the traditional way of teaching and learning that was created to be centered around Whiteness and the way that we perceive intelligence and learning. It wasn't until my undergraduate studies that I finally got to "do" science. Going into the field, working with wildlife and studying nature, asking questions and developing ways to answer them, practicing data collection, coming to conclusions with data, meeting actual scientists, and having an actual purpose for the work that transcended the classroom is when I truly loved science and knew that I wanted to go into the field. This realization led me to wonder what science would be like if I hadn't been good at the traditional way of learning, or if I hadn't grown up being molded into what society deems as "high achieving." What happens to the students who may be scientists at heart but who were discouraged during high school science? How many valuable individuals was the world missing out on because of the way that science is traditionally taught? During my research at Hamline, those questions began to form answers. Students who aren't perceived as high achieving in high school science are overwhelmingly students of Color. Knowing that one race isn't inherently better, smarter, or harder-working than any other, this could only mean that something was happening in schools that was excluding students of Color from engaging in the science curriculum and thus from the potential of going into science in the future. This is where my drive to change the system started. I knew that if I was going to be a science educator, I had to make a commitment to making sure that my BIPOC students were supported in a way that helps to facilitate and untap their potential for learning science, doing science, and making significant scientific contributions to society.

My Time as A Teacher

Having my first year of teaching be during a global pandemic has been less than ideal and presents new challenges as far as science education goes, but it has provided insight into what works and what doesn't when you are trying to engage students in the science process. My district is very intentional about isolating race when looking at data, and at the beginning of the year the students who were struggling the most were overwhelmingly students of Color. Science was not meant to be taught over the computer, and during distance learning it was nearly impossible to create engaging, inquiry-based lessons. Try as I may, lessons were predominantly lecture-based, highly content-driven, and unfortunately, more traditional. Assessments were mainly tests and quizzes, and labs were certainly out of the question. It was challenging to know that I was not doing as much as I normally would and teaching in a way that I vowed never to do. The students who were succeeding were almost entirely White, and I was reminded of my own high school experience and why that was probably the case. I did what I could to accommodate multiple learning styles, cultural differences, and language barriers, but my BIPOC students were still being vastly underserved educationally. As the world began to open back up and students started returning to school, even small changes that I made in the curriculum seemed to have an impact. I did away with tests and quizzes and assessed students based on effort, participation, and discussion, and stopped assigning work outside of class time. Activities were no longer online and could be hands-on and collaborative. Relationships were being built because I was no longer talking to silent, little black boxes on my computer screen, but interacting with human beings with lives and opinions and their own ways of looking at the world. Unsurprisingly, every single student who returned to school began to increase their grade and engagement with science. Though challenging, teaching in the pandemic reinforced what we already knew: that teaching in ways that promote critical thinking and problem solving and are culturally responsive benefit every single student, most importantly our BIPOC students (I find it important to note that I say most importantly not because any students are more important than others but because White students are being served either way). I decided that I wanted to be more intentional with the way that I plan lessons and make sure that every single day, every single student has the tools that they need to succeed in my classroom. Though that is something that takes time and is a continual educational journey, designing this genetics unit is where I want to start.

Why This is Important

I think that reframing science education around the Next Generation Science Standards (NGSS) (https://www.nextgenscience.org) and culturally relevant pedagogy (Ladson-Billings, 1995) is important not only for myself and the future of my teaching career but for every single student that comes through my classroom. Thankfully, the way in which science standards are being met is in the process of drastically changing from a traditional way of learning that favored rote memorization, minute details, and lack of personalization, to one that involves more inquiry, exploration, and mastering of broad concepts as they relate to the real world. The Next Generation Science Standards employs 3D learning to help students build a cohesive understanding of science as it relates to themselves, their community, and the world around them (https://www.nextgenscience.org/). Science and Engineering best practices, core scientific ideas, and cross-cutting concepts are the three tenants found throughout the NGSS that build off of one another in order to help students develop critical thinking skills, a collaborative mindset, and a scientific curiosity that allows them to use the sciences to help develop themselves as learners and as citizens of the world.

Gloria Ladson-Billings was the first to frame the improvement of equity in education around pedagogy. In her culturally relevant pedagogy framework, "good teaching" is teaching that is committed to collective empowerment rather than individual empowerment (Ladson-Billings, 1995). It requires that teachers guide students to choose academic excellence on their own because they feel empowered to do so. Culturally relevant pedagogy relies on three tenets: 1) students must experience academic success, 2) students must develop and/or maintain cultural competence, and 3) students must develop a critical consciousness through which they challenge current social order (Ladson-Billings, 1995).

Disrupting the current social order and education system is something that has to be done if we want to start promoting a more empowered, equitable space for all students, not just some students. On a classroom level, using the NGSS and culturally relevant pedagogy to create a community of critical thinkers and collaborators who are able to find answers to problems and engage in arguments using evidence develops students who can go on to use those skills to positively contribute to society. Allowing all cultures and ethnicities to be celebrated not only continues to validate all students but also creates citizens who have empathy and respect for peers who are different from them. Allowing students to teach and learn from each other creates confident, caring individuals who value their own voice as well as the voices of others. As educators, I think it can be easy to forget how much of our students' futures are shaped in our classrooms, and our number one priority should be helping students see their own worth and value as individuals in a society where they belong.

Beyond the classroom, I think that the implications of changing the way that science is taught are huge as there are countless BIPOC students whose brilliance the scientific community and world are missing out on. Students who had a positive science experience and who go on to work in a STEM field influence legislation, public policy, the medical community, and agriculture. If there are no people of Color influencing those fields, the cycle of White supremacy continues. Systemic barriers are in place because there are people in place to keep them there. We desperately need more BIPOC representation in these fields and communities in order to influence policy and decision-making that will begin to eradicate the systems that keep White supremacy alive. Today's students are tomorrow's leaders, and as educators we have a responsibility to help students realize their ability to make changes for themselves and their communities. Culturally responsive teaching is often framed in the context of English or Social Studies classrooms, and throughout my teaching journey I have consistently been finding myself wondering what this looks like in a science classroom. How can I, as a science educator, create a more equitable science classroom in order to increase engagement among BIPOC students?

Summary

In chapter one, I discussed why this area of research is important to me and why I have chosen to create the project that I have. My comfort in my own ignorance of racial identity and lack of awareness of the struggles of BIPOC students lead me to feel a great drive to try and change the system that perpetuates the idea that not all students are equally capable of achieving in and engaging with science. My lackluster experience with high school science and reinvigorated love of the field when I was introduced to the true nature of science is what led me to be a science educator and I hope to bring that to my students who many otherwise never experience “doing” science. With this genetics unit I plan to create, my intention is to become more intentional with what I’m doing every day in order to create an equitable science classroom that not only fosters skills needed to be productive members of society but creates empathy and respect for self and others. My hope is that reframing the science curriculum using the Next Generation Science Standards and using influences from culturally relevant pedagogy will increase engagement among BIPOC students and create a classroom community where all voices are heard, accepted, and where students feel like their whole selves are validated.

Chapter two will discuss the research that has influenced my capstone direction. Topics in chapter two include the history of racism, Whiteness, and science, the culturally laden nature of science, an exploration into why BIPOC students are not succeeding in science and what we can do differently as science teachers to change that narrative. In chapter three I will introduce my project while outlining the theoretical framework used to create it as well as the setting, population, and ways that I will assess curriculum effectiveness. Chapter four will include my reflections on the capstone project as well as implications for future use and research.

CHAPTER TWO

Literature Review

Overview

Chapter two aims to explore the research surrounding the role of systemic racism in public schools and discuss the importance of a science education while acknowledging the ways in which BIPOC students have historically been ostracized from the scientific community. It will then discuss the culturally laden nature of science, including how race is not biological, and explore the science teacher's role in both perpetuating racist ideologies in science and dismantling the ways in which they do so. This chapter will conclude with a discussion of the research around how science teachers can start implementing culturally relevant pedagogy, teaching for social justice, and the Next Generation Science Standards in order to answer the question: *How can science educators create a more equitable science classroom in order to increase engagement among BIPOC students?*

History of Racism, Whiteness, and Science

Defining Racism

To fully understand the extent to which racism prevails in the American public school system, it is imperative that there is a clear distinction between prejudice and racism. Limiting our understanding of racism to the definition of prejudice does not explain the way in which racism is deeply embedded into all systems in America. In his book *Portraits of White Racism* (1977), David Wellman defines racism as a "system of advantage based on race." Tatum (2017) furthers this definition by stating that racism is not an individual set of beliefs, but rather a system of "prejudice plus power". It is the social power that comes with being a part of a majority group - access to social, cultural, and economic resources and decision making (Tatum, 2017) combined with racial prejudice that is what allows racism to thrive in our society. In an educational setting, racism can be defined as “any act that, even unwittingly, tolerates, accepts, or reinforces racial unequal opportunities for children to learn and thrive; allows racial inequalities in opportunity as if they are normal and acceptable; or treats people of color as less worthy or less complex than “white” people” (Pollock, 2008).

Systemic Racism in Education

In order to effectively explore the ways in which perceived White “superiority” is upheld in American public schools, it is important to look at the historical weight placed on Whiteness and the ways in which it was and continues to be centered in education and public policy. Systemic racism in schools will never cease to exist if Students of Color are implicitly and explicitly fed the narrative that their stories are somehow less-than. Systemic racism in schools will never cease to exist if White students are fed the narrative that their stories are the only stories worth telling. Systemic racism cannot be dismantled if the ways in which it is upheld are not acknowledged, isolated, dissected, and abolished.

The American education system was built on White supremacy, anti-Blackness, and sexism (Love, 2019), and the repercussions of that are still extremely evident today both outside and inside the classroom. The first public schools in America were only for White, affluent males. The IQ testing movement during the first two and half decades of the twentieth century introduced the concept of “scientific racism,” designed to allow for the classification of humans into distinct biological races and thus allowed for individuals to see groups of people as superior to others (Silverberg, 2008). Redlining in the early decades of the nineteenth century still affects communities today, with poor and minority students being pushed into underperforming, underfunded, and understaffed schools with an over-reliance on standardized testing. American history textbooks are full of nationalistic stories promoting blind patriotism while completely omitting any story where the "hero" isn't a White man. School entrance applications and surveys often require self-identification as either "Caucasian" or "Other." Inside the classroom, systemic racism can be further perpetuated through teachers themselves. Attempts to keep context-neutral classrooms (color blindness) invalidates the existence of students' rich cultural backgrounds. Deficit mindsets toward underrepresented students and higher expectations of White students cause underrepresented students to internalize low expectations of themselves (Sparks et al., 2020). When teachers lack the sociopolitical consciousness that is needed to recognize the roles that each student's identities (race, class, gender, sexual orientation) play in both social and educational inequality, opportunity gaps are seen as achievement gaps and that system-created gap is perpetuated throughout school and into STEM professions (Spark et al., 2020).

Though American students aren't explicitly told that White lives mean more than "Other" lives, that is the narrative that they are constantly inundated with throughout their education. It has become ingrained into our very ways of thinking and believing and it has created a public school system that harms Students of Color and breeds White students who will continue to be part of the problem.

Why is Science Important?

Science achievement gaps along racial, ethnic, socioeconomic, and linguistic lines have significantly widened over the past 20 years in America. Many students in urban schools describe science as a subject that generates boredom, anxiety, confusion, and frustration. In particular, students do not like science because it is not perceived to be connected to their interests or experiences (Basu & Barton, 2005).

Why is science education so important? Since the 1950s, leaders in education, science and politics have emphasized the need for scientific literacy among the population of the United States (Quinn & Cooc, 2015). Today, the importance of scientific literacy is increasing due to the large demand for graduates entering careers in STEM: science, technology, engineering, and math (Quinn & Cooc, 2015). In the coming decades, because of increasing discoveries in and increased funding of science and technology, science occupations are predicted to grow faster than the average rate for all other fields (Quinn & Cooc, 2015), stressing the importance of providing equitable opportunity to all students who may be interested in entering into science as a career.

Developing a more scientifically literate population will undoubtedly require confronting and eliminating the racial and ethnic gaps in perceived science proficiency. These gaps have important implications for economic and technological advancement, and more importantly, implications for social equity. Research into urban science education reform has noted that this issue needs remediation as is it always beneficial to have a range of people from different group identities in a workforce and that those in scientific careers earn almost 26% more than those working in other fields (Banerjee, 2016). Though not every science-learner will enter into the field as a career, it has proven to be an important subject for children to study in school and has implications among many other subjects. Science fosters critical thinking skills, feeds a natural love for learning, opens doors to a number of disciplines, and prepares students for an increasingly science-based and technological future.

Racism in the Scientific Community

Beyond discussions of systemic racism in American public schools, it is important to discuss the inherent racism and bias that have historically plagued the scientific community and how it has impacted the relationship between science and the BIPOC community. This history has implications for how students of Color view science prior to school as well as their willingness to enter into the scientific field professionally. Science's historical role participating in racial discrimination and the lack of BIPOC representation in science has greatly contributed to the systemic inequalities in the sciences that have prevailed for generations and will continue to prevail without immediate intervention.

One of the greatest contributors to the lack of Students of Color interested in pursuing the sciences comes from their lack of representation. African American, Latinx, Native Americans, and Pacific Islanders make up approximately 32.2% of the United States population, but that percentage is not reflected in the STEM workforce (Sparks et al., 2020). Unfortunately, this statistic has been consistent - in 1977, the National Science board reported that only 1.3% of doctoral degrees in natural sciences were awarded to African Americans (Mutegi, 2003). In 1997, that number had grown to only 2.4% (Mutegi, 2003). By 2017, it had increased to just 3% (National Science Foundation, 2020). Smith et al., (2007) introduced the idea of "racial battle fatigue" among scientists of Color, which is the cumulative result of a race-related stress response to experiencing bias, microaggressions, and professional isolation that can impede the academic progress of students and faculty of color. Even when racial battle fatigue can be endured, the next barrier comes in the form of a lack of federal funding. As of 2015, White applicants are approximately 10% more likely to receive federal grants than Black applicants (Hoppe et al., 2019). The data shows an interesting explanation for this that further illustrates the prevalence of systemic racism – in the same study, a keyword search of more than 157,000 applications revealed that “topic choice” explained more than 20% of the funding gap. This is important to note because Black applicants were more likely to request grants for proposals at the population and community levels, while White applicants focused more on the cellular or molecular level (Hoppe et al., 2019). The implications of this realization are huge – not only are Black scientists less likely to receive grants to further their scientific careers, but the research that they could potentially be doing could provide deep insight into how to fix systemic racism issues at the community level.

The Culturally Laden Nature of Science

Race is not Biological

In order to teach students that race is a social construct, it is imperative that science teachers first know enough about genetics to help students understand that race is not biological. According to Mukhopadhyay et al., (2014), there are six scientifically accepted arguments as to why race is a social construct and not a biological fact. McChesney (2015) summarizes these arguments well -

1. People cannot be scientifically divided into racial groups. As race changes depending on where you are and who you are speaking to, race is more a function of biological cline (the biological evolution of a trait across the geographical range of a species). Former President Barack Obama, for example, who has an African Father and European Mother, would typically be seen as White in a place like Brazil but as Black in the United States.

2. There are no relationships between traits that are used to categorize people into races and socially created stereotypes. Visible traits that we associate with race (like skin color) have no correlation with traits like blood type and even less correlation with more complex traits like intelligence.

3. Over time, geography and environment change the genetic structures of human populations through natural selection. Skin color is a result of natural selection – in this case, random mutations in genes that affect the creation of melanin in the skin.

4. There is more diversity within racial groups than between racial groups. Research has shown that the variation within a single population is much higher than variation between "races" in different geographical regions. McChesney (2015) gives the example of the Yoruba, an ethnic group in Western Africa having more variation than Europeans and sub-Saharan Africans of the same "race."

5. All people living today are descended from populations that originated in Africa. All human populations outside of Africa are descended from one band that migrated from Eastern Africa about 60,000 years ago (McChesney, 2015).

6. All people living today are one biological species.

Though these arguments alone may not create a complete shift in paradigm to the fact that race is not biological, they can help lay the groundwork for students to be able to look at race through a different lens. In their book *Racial Formation in the United States*, Omi and Winant (2015) describe race in the United States perfectly: “Race is not something rooted in nature, something that reflects clear and discrete variations in human identity. But race is also not an illusion. While it may not be “real” in a biological sense, race is indeed real as a social category with definite social consequences.``

Mendelian Genetics

Because so many people, including students, hold the belief that race is biological, it’s important to look at the origins of that myth and why it is so heavily perpetuated in American culture. Historically, racial categories developed and promoted by scientists led to a hierarchy of groups seen as biologically superior or inferior (Odekunle, 2020). Though not actually supported by scientific evidence, this idea of “scientific racism” has had devastating effects on predominantly minority communities throughout history. In *Hereditary Genius*, published by Francis Galton in 1869, racially interpreted data concluded that Negroes were at least two grades below Anglo-Saxons in both ability and intelligence (Jackson & Weidman, 2006). Further, Gregor Mendel’s work with pea plants in the 1800’s led people to believe that heredity and genetic traits were the sole predictor of one's abilities. In 1916 Madison Grant offered racial theories of Nordic superiority that led to the Eugenics movement in the United States, stating that “Whether we like to admit it or not, the result of the mixture of two races, in the long run, gives us a race reverting to the more ancient, generalized and lower type” (Jackson & Weidman, 2006). The eugenics movement led Mendel’s work to be used as a model to “improve the human race” through selective breeding of “superior” individuals, and it is

Mendel's work in genetics that we use today as the foundation of our genetics teaching (Sparks et al., 2020).

Cultural influence has also had its hand in developing the scientific ideologies that we hold today. Even famed taxonomist Carl Linnaeus classified humans into four racial categories with traits attributed to each group, which we know isn't based on any sort of actual scientific research. Europeans were described as "active, very smart, inventive," Africans were "crafty, slow, foolish," Native Americans were described as "angry in disposition, obstinate, ill- tempered," and Asians were "melancholy in disposition, severe, and haughty." (Pang Vo, 2004). Though not based in authentic science, these new ideas had devastating implications for the creation of racial ideologies by highlighting the idea that there were inherited racial qualities that could not be erased with education or civilization (Jackson & Weidman, 2006). Throughout history, the gross myth that different races were biologically different has been used to justify colonialism, slavery, genocide, and eugenics and it still influences and sustains policies and ideologies that are widely accepted today (Odekunle, 2020).

The Role of the Science Educator

STEM teachers often believe that these disciplines are culture-free and that speaking of racial prejudice and identity in the classroom is better suited for Social Studies or English classrooms. This viewpoint has likely contributed to the underrepresentation of students of Color in STEM professions. Donovan (2017) found that traditional ways of teaching genetics actually perpetuates the misconception that race is biological and can actually increase racist beliefs among students. Donovan's experiment tested whether talking about "racial traits" in the biology curriculum caused students to develop beliefs about whether or not race was biological, thereby affecting their own racial prejudice. Students in grades 7-9 were randomly assigned within their classrooms to learn either from lessons discussing differences in skeletal structure and the prevalence of genetic disease between races (the racial condition) or identical lessons where traits were not introduced as a function of race (nonracial condition).

After 3 months, Donovan found that compared to students in the nonracial condition, students in racial condition a) grew significantly more in their perception of the amount of genetic variation between races, b) grew in their belief that races differ in intelligence for genetic reasons and c) became significantly less interested in socializing across racial lines and less supportive of policies that reduce racial inequality in education. These findings support the idea that biology education can sustain racial inequality and genetic education could be designed to reduce biologically based racism in the classroom.

Why Aren't BIPOC Students Succeeding in Science?

Before answering how we can increase science achievement among disadvantaged students, it is worth exploring the factors that contribute to this perceived achievement gap. Pinpointing the reasons "why" will help to ensure long-term improvement and get to the root of the problem, rather than providing surface level improvements to appease statistics.

Urban school districts face a multitude of problems. Teachers and students often work under stressful conditions characterized by high rates of truancy, low rates of graduation, and negative attitudes toward school (Banerjee, 2016). There are a number of sub factors that contribute to a lack of a positive attitude toward school and learning. On a larger scale, marginalized groups in urban communities are often plagued by a lack of positive academic role models (Banerjee, 2016). Similarly, qualified teachers and adequate resources are often hard to come by. Unfortunately, there is also a lack of parental involvement in education among urban youth. According to Banerjee et al., (2010), parental involvement in education is one of the biggest predictors of cognitive ability and academic achievement and children who have highly involved parents have better academic outcomes in elementary and secondary school. Importantly, positive effects of parental involvement in education can be seen as early as preschool (Banerjee et al., 2010), so children who do not have involved parents are beginning their academic career behind peers who may have parents who are actively involved in their education.

Unfortunately, marginalized students are often placed in less supportive schools with less supportive teachers, as well. The effects of teacher expectations on students' academic aptitude has been widely studied, and research shows that a student's perceptions of teachers and teachers' attitudes can predict academic performance and discipline. One of the most glaring examples of the negative effects of teacher bias is seen in the lack of representation of minority groups in advanced placement classes. In her article, Confronting the Racism of Low Expectations, Julie Landsman (2004) explores the ways in which minority students are denied access to the same levels of success as their White counterparts based on the way in which students are placed in such classes. It is widely factual that advanced classes are composed mainly of White students, and Landsman (2004) notes that this is because racism is still embedded within many teachers' belief systems, consciously or not. Educators may assume that minority students are unable to do assigned work, that they come from a dysfunctional family, and that they are innately less intelligent than their White peers (Landsman, 2004). Research has shown that members of stigmatized groups are more susceptible to teacher bias than students who are not members of these groups, and these biases can lead to both self-fulfilling prophecies and self-maintaining expectations (Van de Bergh et al., 2010). Unless today's educators can acknowledge that this underlying racism exists, we will be unable to fix the system that is keeping minorities out of advanced programs and creating lower expectations of underrepresented groups.

Works in science education have shown that science is learned in a context and students make decisions about how, where, and when science knowledge is useful to them based on their individual sociocultural knowledge and experiences (Upadhyay et al., 2017). Perhaps one of the most substantial factors contributing to a lower science achievement among disadvantaged students is that many of them learn science ideas and topics decontextualized from their own sociocultural experiences, making science learning less meaningful (Upadhyay et al., 2017).

Addressing barriers to learning for disadvantaged students is crucial when discussing ways to increase science achievement. Classrooms in urban school districts are often under-resourced and over-populated, and these factors (along with a lower salary) rarely attract the most highly qualified teachers. Students may have a lack of positive academic role models to model their scholastic aptitude after, and a lack of parental involvement altogether can also be a problem. Teacher bias and low expectations often plague urban school districts, and the systemic racism that is in place often prevents marginalized students from entering advanced placement or college preparatory courses. Positively, perhaps the most glaring factor contributing to lower science achievement among disadvantaged students is the one that may be easiest to change. Marginalized students often feel disconnected to science learning as it can exclude sociocultural experiences from the classroom, so increasing interest in the sciences needs to start with creating a more equitable science curriculum for all students.

How Can We Teach Science Differently?

Culturally Relevant Teaching

Gloria Ladson-Billings defines culturally relevant teaching as a pedagogy of opposition (Ladson-Billings, 1995). She formed the theory of culturally relevant pedagogy in order to address and challenge deficit views of African American students and their academic success. Ladson-Billings (1995) defines CRP as a "theoretical model that not only addresses student achievement but also helps students to accept and affirm their cultural identity while developing critical perspectives that challenge inequities that schools and other institutions perpetuate." CRP is a way to "empower students intellectually, socially, emotionally, and politically by using cultural references to impart knowledge, skills, and attitudes." Ladson-Billings suggests that educators reframe how we think about and teach our students who are marginalized from the need to be fixed to a place that acknowledges the cultural assets that each and every student brings to our classroom.

Culturally relevant pedagogy encompasses three criteria: a) students must experience academic success, b) students must develop and maintain cultural competence, and c) students must develop a critical consciousness that they use in the classroom and beyond to challenge the inequities of the current social order (Ladson-Billings, 1995). In a science classroom, the curriculum, content, and teaching strategies for students of differing cultural, ethnic, linguistic, and racial backgrounds should offer students continuous opportunities to learn and use scientific knowledge while allowing them to utilize their own personal knowledge and skills in order to make science learning more relevant. Further, science curriculum can and should connect the multiple identities of students, as the student-teacher relationship can't properly develop without teachers getting to know the multiple identities of their students (Mensah, 2021).

Ladson-Billings (1995) reflects on an example that she witnessed where a White female educator demonstrated culturally relevant teaching in her classroom. This particular teacher emphasized cultural competence by creating an "artist or in-person residence" program so that students could learn from each other's parents and gain cultural knowledge. This teacher invited parents to come into the class and demonstrate skills for the students. One parent who was known in this particular community for amazing sweet potato pies did a two-day residency where she taught students to make pie crust. The class ate the pies the following day and then were asked to conduct additional research on various things that they learned. Students did reports on George Washington Carver and his sweet potato research, conducted taste tests, created marketing plans for selling pies, and researched aspects of the culinary arts to find out how one becomes a chef (Ladson-Billings, 1995). Through this, this teacher's students came to understand how things such as art, excellence, and knowledge are constructed while learning about how where they came from had immense value that was worthy of being shared with the world.

Teaching for Social Justice

Teaching for social justice is often described as an updated and reimagined version of multicultural education, which came about during the civil rights movement in the 1960s (Cho, 2017). Conceptually, teaching for social justice differs from other forms of multicultural education because it pays more attention to societal structures that perpetuate social injustices than it does to the issue of cultural diversity (McDonald & Zeichner, 2009). Teaching for social justice should seek to answer the question, "What kind of education do students need in order to become agents for social justice?" (Cho, 2017). Students should leave a classroom with a focus on social justice with a broader view of the world, a realization of the inequities that reside within it, and a deep desire to be an agent of change within those systems. According to McDonald (2008), there are four dimensions of a successful practice focused on social justice. These include 1) meeting individual students' needs and providing differentiated support, 2) recognizing student opportunity to learn in ways that are responsive to their identities (English language learners, students with special needs, etc), 3) recognizing student opportunity to learn in ways that are responsive to students' affiliation with racial, ethnic, and socioeconomic groups, and 4) resisting the systemic inequities that are present in society (McDonald, 2008).

North (2009) contends that teaching for social justice seeks to develop multiple literacies within each student in order to allow them to fully experience academic success while contributing to the betterment of society by being passionate about social justice. In this instance, literacy goes beyond reading and math literacy and extends to functional, critical, relational, democratic, and visionary literacy.

Functional literacy refers to the ability to live as an autonomous and informed citizen, and teachers who promote this include in their curriculum opportunities to develop skills for higher-order thinking (North, 2009). Developing the capacity for higher-order thinking is an essential skill that is needed in order to succeed in our competitive society. The ability to analyze, synthesize, and evaluate information is crucial when molding citizens who are going to be instrumental in the uncovering and dismantling of injustices and oppression.

Critical literacy is the ability to challenge existing ways of knowing, question institutionalized power relations, and create and implement strategies for increased equality and social justice (North, 2009). Teachers who allow students to develop critical literacy allow for the analysis of different texts to find underlying messages about who is benefitting, who is left out, and who knowledge claims were created for. Students need to be able to critically analyze information in order to point out injustices in what they’re being presented.

Relational literacy is the ability to relate to other human beings. Addressing others without prejudice or bias and developing the ability and will to care for others beyond school and the classroom is imperative to being a functioning member of a just society. Teachers who develop relational literacy are co-learners in the classroom, developing relationships with students founded in mutual trust, respect, and the knowledge that each student brings their own unique set of skills. North (2009) notes that relational literacy cannot be taught, but that students can only understand it and its importance when teachers treat them with respect and there is a joint teacher-student responsibility for learning.

Democratic literacy refers to the ability and will to promote the common good (North, 2009). Students need education and skills that will empower them to resist conformity and question a Western-centric code of behavior where dissent is unfavorable, and teachers must incorporate diverse cultural and ethnic communication styles and help students practice making decisions and having discussion across despite differences in opinion (North, 2009). The purpose of being democratically literate is for students to become engaged citizens with the ability to reform communities.

Finally, visionary literacy allows students to see a future where they can play a role in promoting social justice. Developing self-confidence and self-worth that allow students to know that they can make a difference is a key way to develop visionary literacy in the classroom.

All types of literacy discussed are capable of being developed by employing certain strategies each and every day in the classroom: connecting student lives, linking content to real-work problems using multiple perspectives, creating classroom community, and including opportunity for authentic assessment are all strategies that should be instrumental in the day-to-day of a classroom that is focused on teaching for social justice.

The Next Generation Science Standards

The Next Generation Science Standards (NGSS) were developed as a multi-state effort to create science standards that focused less on rote memorization of terms and traditional science teaching and more on critical thinking, inquiry, and viewing the world through a science-focused lens. Within the NGSS, there are three important dimensions to learning science that must all be combined to help build logical and cohesive understanding of science over time, referred to as “three-dimensional learning”: crosscutting concepts, science and engineering practices, and disciplinary core ideas (https://www.nextgenscience.org/).

Within the Next Generation Science Standards, crosscutting concepts are a way to link the different domains of science so students are able to recognize that these domains build upon one another and do not exist as separate from one another. According to the National Research Council, these domains include: patterns, similarity, and diversity; cause and effect; scale, proportion and quantity; systems and system models; energy and matter; structure and function; and stability and change. The NGSS Framework notes that these concepts need to be made clear and explicit for students because they provide a way to organize information for connecting knowledge from various science fields into a scientifically-based view of the world.

Science and engineering practices refer to specific ways that scientists “do” science. Investigation, modelling, and developing theories about the world all contribute to scientific inquiry, a practice that the NGSS intend to develop. This dimension is meant to create an overlap between inquiry-based learning and engineering design, as scientific inquiry involves the posing of a question that can be answered through investigation, while engineering design involves the creation of a problem that can be solved through design. Strengthening both the inquiry and the engineering aspects of the Next Generation Science Standards will help to clarify for students the relevance of science, technology, engineering and mathematics (STEM) to their own personal lives.

The final dimension, disciplinary core ideas, refers to the most important aspects of science. According to the National Research Council, to be considered a core idea an idea should include at least two of the following, but ideally all four (taken from the NRC Framework):

1. Have broad importance across multiple sciences or engineering disciplines or be a key organizing concept of a single discipline;
2. Provide a key tool for understanding or investigating more complex ideas and solving problems;
3. Relate to the interests and life experiences of students or be connected to societal or personal concerns that require scientific or technological knowledge;
4. Be teachable and learnable over multiple grades at increasing levels of depth and sophistication.

Modes of Assessment

Cian et. Al (2019) developed a guide for providing formative assessments for addressing the three domains within the Next Generation Science Standards. Using three different models, they pinpointed ways that students can be supported while navigating the NGSS through formative assessments: the sequential model, the concurrent model, and the embedded model. In my project, I will be focusing on using the sequential model for assessment in order to explore each domain separately in order to lead to an overall stronger understanding of the objectives within each domain.

Sequential models for assessment are best used when teachers are wanting to guide students to explore objectives associated within a domain in order to gain a deeper understanding of their expectations. In this model, the three domains are addressed separately so students are able to master each one before moving on to the next. In the example lesson provided, the lesson progresses from disciplinary core concepts, to science and engineering practices, to cross-cutting concepts. For instance, consider that a high school Earth and space science performance expectation is: "Construct an argument based on evidence about the simultaneous co-evolution of Earth's systems and life on Earth" (HSESS2-7). To successfully accomplish this objective according to the NGSS, students must understand the disciplinary core idea of biogeology, the cross-cutting concepts of how this idea reflects stability and change, and they must be able to represent their understanding of science and engineering practices using an evidence-based argument (Cain et. al, 2019). A sequential model would be useful in this instance to ensure that students are properly supported throughout the entire lesson and are confident in their ability to construct an argument with evidence based on their research. Cain et al (2019) suggest first giving students a See, Think, Wonder assessment while viewing a video about a meteor strike in the prehistoric era to assess disciplinary core ideas. Students can write down their observations, what they think happened, and what they wonder about the event. Following this activity should be a discussion leading to the formation of a statement describing how changes in environmental systems lead to a change in life. Students could then research other examples of this same idea, put together a concept map about the themes of stability and change (cross-cutting concepts), and present it to classmates in a jigsaw format. The final assessment, meant to assess science and engineering practices, could include students developing an argument about how human activity can jeopardize life through the changing of geological or chemical processes. This could be in the form of a paper or a Predict-Observe-Explain activity, where students make a prediction about the consequences of a change, discuss what they have seen to suggest this outcome may occur, and explain why they make the connection between these observations and their prediction. (Cain et al, 2019).

When shifting the framework of curriculum to be more culturally responsive, it is not enough to simply reassess teaching strategies or change methods of assessment. Educators need to research, acknowledge, and dismantle the ways that they contribute to BIPOC student disengagement, employ tenants from culturally responsive pedagogy, all while creating objectives that align with the Next Generation Science Standards. Teachers can then begin to frame answers to the question: *How can science educators create a more equitable science classroom in order to increase engagement among BIPOC students?*

Summary

Chapter two reviewed current literature around the history of racism, Whiteness, and science, and how it has contributed significantly to the relationship between school, science, and the BIPOC community.   Research shows that teacher bias, the way we view "achievement," a lack of role models, and the traditional way in which science is taught has contributed to a lack of engagement among BIPOC students and thus a disproportionate amount of these students not entering into STEM fields as careers. Changing this narrative will involve changing the way that we teach science and the way in which we create curriculum. The Next Generation Science Standards were created to influence curriculum to be more concept based, with the focus being on problem solving, critical thinking, and collaboration. NGSS emphasizes discovery and inquiry-based science that focuses on students developing questions and finding solutions through experimentation and discovery. Beyond content, science classrooms need to be more culturally responsive. Culturally relevant pedagogy is a concept that is grounded in teachers displaying cultural competence and creating a safe, validating space for every race, ethnicity, and culture. Merging these two concepts will help to create a generation of BIPOC students who are more engaged in the scientific process and a generation of White students who want to be agents of change. Chapter three outlines the intended curriculum project and how I plan to incorporate both the Next Generation Science Standards and culturally relevant pedagogy into a high school genetics unit.

CHAPTER THREE

Project Description

Overview

In this chapter I will describe a high school biology genetics unit that I plan to build, including related standards, methods, and strategies that will be included in each lesson plan. A proposed assessment project is included. The unit will be designed using the Next Generation Science Standards (NGSS) and considerations from culturally relevant pedagogy (CRP). The intent of this project is to take a historically memorization-based biology unit and make it more aligned with both culturally relevant teaching and the Next Generation Science Standards in order to make science education more equitable for all students.

With an increase in technological advancements and importance of topics like clean energy and climate change, careers in STEM fields are increasing at an extremely high rate. As chapter two explained, research has shown that BIPOC students are far less likely to enter into scientific fields after high school. This can be attributed to a number of systemic factors, stemming from a historically White centered science curriculum, lack of science role models, and a feeling of science not being relevant to students' lives or cultures. Traditionally, science education has been focused on vocabulary, memorization, and a "teacher-as-leader" mentality. Though this may work for some students, science education needs to be reframed through the lens of inquiry, exploration, critical thinking, and culturally relevant strategies in order to give BIPOC students an equitable chance at science engagement. This unit development process was guided by the research question:

How can science educators create a more equitable science classroom in order to increase engagement among BIPOC students?

Theoretical Framework

In order to determine how the unit would be created, I utilized two frameworks: NGSS storylines and backward design. Within the Next Generation Science Standards, the instructional strategy using storylines aims to influence curriculum based on student-generated questions. According to the National Research Council, storylines are coherent sequences of lessons that are specifically driven by students' questions that they develop after interacting with scientific phenomena. At each step of the storyline, students use science and engineering practices to come up with questions and figure out scientific ideas. Each step also creates questions that lead to the next step of the storyline (National Research Council). Storylines create a clear path toward building core ideas and crosscutting concepts that are structured around questions that students themselves come up with. Students should be involved in co-constructing the questions and can thus see instructional activities as helping them to find answers to their questions, rather than just learning content because they're told to do so. For this project, I plan to build the unit around a storyline sequence involving genetics using guiding questions as the initial structure while leaving space for future student questions to additionally shape the unit. The unit will be designed so that lessons can be modified and rearranged should students inquire about phenomena in a different order than I did. To most efficiently create the storyline, I will use a storyline template laid out by the Exploratorium Teacher Institute (2018) to guide my curriculum design. Subsequent design of the curriculum will then be based off of the template and planning will follow the method of backward design.

In backward design, learning activities and assessment are guided by the learning outcomes of the lesson (Loberti et al., 2018). Traditional approach to curriculum design typically involves planning in a “forward design” manner, meaning educators consider the learning activities first, develop assessments around said learning activities, and then attempt to draw connections to the learning goals of the objectives (Bowen, 2017). In contrast, the backward design approach has educators consider the learning goals and objectives of the lesson first. Once the learning goals have been established, the second stage of design involves deciding the best way that students can be assessed on how well they have met said objectives or learning goals (Bowen, 2017). The backward design framework encourages educators to consider these “big picture” learning goals and how students will be assessed prior to deciding on how to teach the content. For this reason, backward design is considered a much more intentional approach to curriculum plan than more traditional methods of curriculum design (Bowen, 2017).

Description of Project

In order to create a unit that ties together a need for culturally relevant science teaching and teaching for social justice, I am building a high school biology unit centered around genetics using strategies from culturally relevant teaching research and teaching for social justice research proven to increase engagement among BIPOC students. As was explored in chapter two, Donovan (2017) found that traditional ways of teaching genetics can perpetuate harmful ideologies and actually increase racist beliefs among students while alienating students of Color, so I wanted to take on the challenge of shifting the narrative of traditional genetics teaching to one that is more culturally relevant and socially conscious.

In order to be active, positive members of society, students not only need literacy and numeracy skills, but they must have experience in developing their social, cultural, and political skills as well (Ladson-Billings, 1995). Gloria Ladson-Billings (1995) addresses this with her theory of culturally relevant pedagogy that is grounded in high academic expectations and the development of cultural and critical consciousness among students. Ladson-Billings (1995) developed this framework to address the ways in which BIPOC students have been underserved by public education and throughout her studies found that successful teachers of traditionally underserved students consistently employed these three tenets in their classrooms.

Teaching for social justice is also a theory that I plan to ground my unit design in. As outlined in chapter two, teaching for social justice should seek to answer the question, “What kind of education do students need in order to become agents for social justice?” (Cho, 2017). The main goal of teaching for social justice is that students leave the classroom with a broader view of the world, an understanding of the inequities that reside within this world, and a calling to be an agent of change within those systems. The four tenets of teaching for social justice that will influence my unit design are 1) the importance of meeting individual students’ needs and providing differentiated support, 2) allowing for opportunity to learn in ways that are responsive to each students identities, 3) allowing for opportunity to learn in ways that are responsive to students’ affiliation with racial, ethnic, and socioeconomic groups, and 4) resisting the systemic inequities that are present in current society (McDonald, 2008).

The unit will be aligned with the Next Generation Science Standards (National Research Council, n.d.) and will include an exploration of DNA, cells, and genetic information. Students will learn about DNA and proteins, cell division and genetic variation, and explore mutations and probabilities. The culminating project will be a research-based project where students will use what they have learned about genetics and ethics to dig deeper on a subject of their choice and relate it to themselves and their communities. The focus of this unit is learning through storylines and culturally relevant teaching strategies while hitting the benchmarks laid out by the Next Generation Science Standards. According to the National Resource Council, a storyline is a sequence of lessons where each step is driven solely by the students' questions that arise after observing a scientific phenomenon (National Research Council, n.d.). At any given time, students should be able to answer the question, "What are you doing and why?" by explaining a question or problem they are trying to figure out (National Research Council, n.d.)

I plan to use sequential assessment models to assess the NGSS standards and use a variety of instructional strategies from my Science Teaching Methods Course. Sequential models for assessment are used to guide students to explore objectives associated with a topic in order to gain a deeper understanding of the Science and Engineering practices, cross-cutting concepts, and core ideas used to master that objective (Cain et. al, 2019). In this model, objectives are addressed separately so students are able to master each one before moving on to the next.

I will attach an online version of all materials, including lesson plans, teacher notes, and any activities, labs and worksheets that accompany the unit. The next section will outline the specific NGSS standards that my project will be aligned with. This will include the outcomes and objectives, disciplinary core ideas, science and engineering practices, and cross-cutting concepts.

NGSS Standards (Disciplinary Core Ideas)

LS1.A: Structure and Function

- All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins. *(secondary to HS-LS3-1) (Note: This Disciplinary Core Idea is also addressed by HS-LS1-1.)*

LS1.B: Growth and Development of Organisms

- In multicellular organisms individual cells grow and then divide via a process called mitosis, thereby allowing the organism to grow. The organism begins as a single cell (fertilized egg) that divides successively to produce many cells, with each parent cell passing identical genetic material (two variants of each chromosome pair) to both daughter cells. Cellular division and differentiation produce and maintain a complex organism, composed of systems of tissues and organs that work together to meet the needs of the whole organism. (HS-LS1-4)

LS3.A: Inheritance of Traits

- Each chromosome consists of a single very long DNA molecule, and each gene on the chromosome is a particular segment of that DNA. The instructions for forming species' characteristics are carried in DNA. All cells in an organism have the same genetic content, but the genes used (expressed) by the cell may be regulated in different ways. Not all DNA codes for a protein; some segments of

DNA are involved in regulatory or structural functions, and some have no as-yet known function. (HS-LS3-1)

LS3.B: Variation of Traits

- In sexual reproduction, chromosomes can sometimes swap sections during the process of meiosis (cell division), thereby creating new genetic combinations and thus more genetic variation. Although DNA replication is tightly regulated and remarkably accurate, errors do occur and result in mutations, which are also a source of genetic variation. Environmental factors can also cause mutations in genes, and viable mutations are inherited. (HS-LS3-2)
- Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus the variation and distribution of traits observed depends on both genetic and environmental factors. (HS-LS3-2),(HS-LS3-3)

NGSS Science and Engineering Practices

- Asking questions and defining problems
- Developing and using models
- Analyzing and interpreting data
- Engaging in argument from evidence

NGSS Cross-cutting Concepts

- Cause and Effect
- Scale, Proportion, and Quantity
- Systems and System Models
- Science is a Human Endeavor

Learner Outcomes/Objectives

HS-LS1-4. Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms. [*Assessment Boundary: Assessment does not include specific gene control mechanisms or rote memorization of the steps of mitosis.*]

HS-LS3-1. Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring. [*Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process.*]

HS-LS3-2. Make and defend a claim based on evidence that inheritable genetic variations may result from (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors. [Clarification Statement: Emphasis is on using data to support arguments for the way variation occurs.] [*Assessment Boundary: Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process*.]

HS-LS3-3. Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population. [Clarification Statement: Emphasis is on the use of mathematics to describe the probability of traits as it relates to genetic and environmental factors in the expression of traits.] [*Assessment Boundary: Assessment does not include Hardy-Weinberg calculations.*]

Setting

The units described would be written for use in a high school biology classroom. The author of this unit teaches at a public suburban high school in the Midwest that serves approximately 5,000 students. According to the district profile, student demographics are as follows: 0.6% American Indian/Alaska Native, 3.4% Asian, 20.4% Black/African American, 11.9% Hispanic/Latino, 9.1% 2 or more races, and 54.3% White. Residents make up 83% of the District's student population, while the other 17% are open-enrolled students. Further demographics include:

- English Language Learners make up 11% of students
- Students and their families speak 49 different home languages
- 36.1 percent of the student population qualifies for free and reduced meals
- 11.2 percent of the student population qualifies for Special Education services
- 10.1 percent of the student population is part of the District's Gifted and Talented Programs

This district prides itself on their focus of racial equity. Dialogue isolates rate and attempts to make intentional connections to what is personal and local both for educators and for learners in classrooms and programs.

Population/Participants

This curriculum was designed for a general biology classroom. In this district, this class is a two-semester course with a passing grade required for graduation. Concepts covered in general biology include the structure and function of cells, photosynthesis, cellular respiration, genetics, viruses and prokaryotes, and more. The course is typically designed so that students are encouraged to question how things work in the world and are guided in how to take these questions and design a scientific exploration. Because this course is required for graduation and not an elective, it usually comprises many students who are not yet interested in the sciences. In this district, biology is taken in 11th grade, after chemistry which is taken in 10th. In my experience in talking with students at this district, many felt that chemistry made them more weary of science and felt it wasn't particularly applicable to their lives outside of school. It is my hope that this genetics unit can begin to shift the mindset of those students who don't feel a connection to science.

Assessment of Curriculum Effectiveness

In order to assess if the curriculum was successful, I will be using student interviews conducted before and after completion of the unit. All students who feel comfortable will be interviewed. In regards to science itself, interviews will consist of questions about students' views of science, their self-assessed level of engagement with previous science classes, and interest in the sciences as a career. In regards to the cultural responsiveness of science, interviews will include questions about whether or not students feel that science in relevant to their lives, if they have ever seen their culture represented or celebrated in science classes, if they feel science is important to their community, and if they have any positive role models in the sciences. Similar questions will be provided before and after the unit to see whether or not students' perception of science changed after one unit that incorporates both the Next Generation Science Standards and culturally relevant pedagogy. It is important to note that questions will be differentiated based on student needs and comfort level with academic language.

Sample Interview Questions

Pre-Unit:

1. How do you identify in terms of race?
2. As you enter 10th grade, what is your relationship with science thus far (do you enjoy it? Why/why not?)
3. How would you describe your level of engagement in previous science classes? Explain.
4. Are you interested in pursuing science as a career? Why or why not?
5. Do you feel as though science is relevant to your life outside of school?
6. Do you feel as though science is relevant to your community?
7. Have you felt represented or celebrated in previous science classes?
8. Do you have any positive role models in the sciences?

Post-Unit:

1. Has your relationship with science changed now that this unit is complete?
2. How would you describe your engagement in class during this unit?
3. Are you potentially interested in pursuing science as a career?
4. Do you feel as though science is relevant to your life outside of school?
5. Do you feel as though science is relevant to your community?
6. Do you feel represented or celebrated in this science class?
7. Do you have any positive role models in the sciences?

Summary

Chapter three included an outline of the intended curriculum project including relevant standards from the NGSS to be met. Cross-cutting concepts, science and engineering practices, and learner outcomes were also stated. The setting and participants were outlined, as well as the methods that I plan to use to create the curriculum. Finally, an overview of the assessments that will be used to assess curriculum effectiveness was given. Chapter four will include the outcomes and reflections of the curriculum design process.

CHAPTER FOUR

Reflection

Overview

The creation of this project sought to utilize culturally relevant pedagogy and the Next Generation Science Standards to create a 10th grade Biology unit exploring genetics through an equity and race-based lens. The purpose of this project was to answer the question: *How can science educators create a more equitable science classroom in order to increase engagement among BIPOC students?* This chapter examines important ideas, concepts, and lessons learned throughout the curriculum development process. Next, major influences from the literature review are discussed as well as limitations that arose during development. Possible policy implications are also explored. Finally, possible future research and contributions to the profession are identified.

Curriculum Development

Major Learnings

Throughout this project, my major learnings came throughout the actual curriculum development. Most importantly, I learned how imperative it is to be intentional about lesson planning. My previous experience with lesson planning was mainly only in my courses at Hamline. Admittedly, during my first year of teaching, I definitely created lessons using a more forward approach - choose the topic, pick the activities to go with it, and then decide on a meaningless assessment. I was focused more on the activities being enjoyable than I was on the actual learning that was happening. There was very little intentionality. Did students enjoy themselves? Yes. Did I use that as a basis of my teaching abilities? Yes. Did they actually learn anything? I don’t really know. This process has had major implications for the way I plan to create lessons in the future, and I am going to go into curriculum development with a new way of thinking and planning so that every year when I ask myself "did they really learn anything?" I can answer confidently with "yes."

Another major learning that I encountered is the absolute importance of looking at the history of what I am teaching and asking myself:

1. Who did this benefit?
2. Who did this exclude?
3. What information are we missing?
4. What implications does this have on science now?

I have realized that nearly everything I learned in school was extremely Euro-centric and vital people and stories were left out of that history. Even with a subject like science, when you start to ask yourself these questions you really discover a whole world of information that is necessary to know in order to have a complete picture of how scientific history has shaped science today. There is endless literature detailing the ways in which BIPOC students feel ostracised from science and how that starts in school, and a major reason for that is that science teachers can feel that discussion of race and history are better left to the humanities courses. In actuality, there is a whole blind spot of scientific history involving race that needs to be included in curriculum so students can know the ways in which science can be and has been used to alienate people and how effects of that are still seen and felt today. Winston Churchill's (1948) famous quote, "those that fail to learn from history are condemned to repeat it" really resonates here, as students can't want to change the social order if they aren't aware of the ways that the social order has been perpetuated far before their time and within every aspect of our history (it is worth noting that even looking into the history and personal life of Winston Churchill, a man whom many idealize, uncovers many controversial ideologies that aren't often spoken about). It is my hope that students are able to practice this way of questioning in my classroom and take it with them throughout their lives.

Valuable Literature

As this was the first curriculum I have attempted to develop on my own, I found it to be an extremely invaluable experience. I found my literature influences came from the theoretical frameworks I chose to base the unit in as well as the strategies I implemented in each lesson from culturally relevant pedagogy. Having a clear framework for development was crucial, and I found both the Next Generation Science Standards storylines and Backward Design to be excellent ways to streamline my thinking and create lessons with more intention. Looking at Culturally Relevant Pedagogy allowed me to think of ways to help guide students to develop their critical perspectives so they can use science to help challenge social inequities.

NGSS storylines aim to empower students in the scientific process by giving them a voice in their science education (McNeill, 2020). Each step in a unit grounded in storylines is driven by student questions about scientific phenomena. This method supports students in understanding not only what they are doing but why they are doing it and how that connects to their lives and communities outside of school (McNeill, 2020). In turn, students are highly engaged in storylines because they are able to see how each investigation brings them closer to explaining a phenomena or answering a question. Because these units are guided by questions, I began the unit by asking myself anchoring questions about the scientific processes and how they might relate to the world of 10 grade students and used those questions to create a potential "road map" of the genetics unit. Because each subsequent lesson is ideally guided by student inquiry, it is critical that the lessons are flexible and able to be shifted around in case student logic goes a different direction than mine did when creating the unit.

Backward Design aims to increase student engagement and transferable learning by changing the order in which curriculum design is usually created. Traditionally, unit planning would start with identifying content to be covered, planning activities to teach that content, and then coming up with an assessment to measure the learnings that should have taken place. Backward design eliminates the lessons with questionable value ("filler" content) and is intended to create more intentional lessons marked by transferable learning (Gonzalez, 2020). In backward design, what students should be able to do is identified first, followed by creation of an assessment to see if students were able to meet that objective. It isn't until these two aspects are created that the learning cycle of activities is intentionally created by finding the best ways to get students to meet the objective. Admittedly, this was a difficult process to get used to, and I often had considerable difficulty rewiring my brain to not start planning leading with activities. It can also be difficult to come up with an assessment before you know what you're going to do that day, but the end result absolutely feels more genuine and intentional and I look forward to using this framework in future unit design.

Culturally Relevant Pedagogy, developed by Gloria Ladson-Billings, is a theoretical model that focuses on three aspects of student achievement while continuously upholding each students' cultural identities (Ladson-Billings, 1994). My interest in creating a culturally responsive science unit first stemmed from conversations with fellow science educators about the difficulty of doing so in the sciences. Through my research, I read that STEM teachers often believe that these disciplines are culture-free and that speaking of racial prejudice and identity in the classroom is better suited for Social Studies or English classrooms. Knowing that this viewpoint has likely contributed to the underrepresentation of students of Color in STEM professions, I knew there had to be ways to incorporate race and equity topics into science classes. Further, Donovan (2017) found that traditional ways of teaching genetics actually perpetuates the misconception that race is biological and can actually increase racist beliefs among students, and as a biology teacher, I don't want even one student to leave my classroom having taken that idea away from my class. Culturally Relevant Pedagogy is based around three aspects of student achievement: student learning, cultural competence, and critical consciousness. According to Ladson-Billings (1994), student learning refers to students' intellectual growth and moral development as well as their ability to problem solve and think critically. Cultural competence is a set of skills that allows students to affirm and appreciate their culture while exploring and appreciating other cultures as well (Ladson-Billings, 1994). Critical consciousness refers to students' ability to identify, examine, and solve problems, particularly those in the real world that contribute to social inequities. I attempted to incorporate ways to develop each of these pillars throughout my unit.

Limitations

Ironically, the same frameworks that proved to be extremely valuable in curriculum development were also the sources of the main limitations in developing the unit. Both the NGSS storylines and Culturally Relevant Pedagogy are highly influenced by the same idea: student voice. They both seek to include students and student ideas in the planning process and implementation of daily activities. It is both the individual student and class as a whole that determines the direction that the unit flows, so creating a curriculum without actual students was a major limitation.

The main tenant of NGSS storylines is that they are mainly guided by questions that students have, so it was extremely difficult to approach this from a student perspective and try to guide the unit from that lens. Without students involved to actually ask questions, there is a huge possibility that when I implement this lesson it will go in a completely different direction than I had originally intended. To attempt to account for this, I tried to make the unit pretty flexible so lessons could be moved around and the unit could flow in a way that made sense to different groups of students. I anticipate that each year that I teach this it will look different based on different classes, but I think that’s part of the ingenuity of storylines. That the learning is guided by the students and they’re allowed to give meaning to their own academic and scientific journey.

As encountered with NGSS storylines, Culturally Relevant Pedagogy is also a difficult methodology to “plan” for. Gloria Ladson-Billings (1995) stated that a common misconception when engaging with Culturally Relevant Pedagogy is believing that successful teaching is about what to do. A main takeaway from my research of CRP is that successful teaching is primarily about how we think. How we think about our students, their communities and broad social contexts and about our curriculum, our instruction, and our role as educators (Escudero, 2019). A huge aspect of CRP is that it is guided by our specific students. Who they are as people, as learners, and community members, and their specific histories and contexts (Ladson-Billings, 1995). What I think was a valuable lesson to take away from this project is that CRP can't just be a "strategy" or a "framework" that I use to create lessons - it has to be woven into every aspect of my thoughts and actions as a teacher.

Benefit to Profession & Implications

It is my hope that if teachers were to use aspects of this genetics unit in their classrooms that they would feel more comfortable integrating discussions around racial inequities and cultural competencies into future science units. I think it's extremely important to begin to frame science learning around a more inclusive curriculum to try to close the opportunity gap that is present in current science education. Further, with the current discussion around the inclusion of Critical Race Theory in American schools, I think that it is imperative that as teachers we are able to explore the ways in which race intersects with systems in this country. How institutions, including schools and the scientific community, can be racist both intentionally and unintentionally. In experience speaking with peers and colleagues, a huge hurdle when beginning to frame science teaching through a Culturally Relevant lens is knowing where to start. My intention with this unit is to have a baseline of ideas embedded into a genetics unit that can be modified and utilized as each teacher sees fit. As science teachers, we have a unique opportunity to approach this subject with data and logic while encouraging arguing using evidence and having productive discussions about past and future implications of racism within the sciences. I believe that school and learning should be intersectional - subjects should not be so separated. Including aspects of history and social studies and civics into a science curriculum makes science more intentionally contextual and allows students to better frame science around their own lives and the connections that it has to their own communities.

I believe that creating a genetics unit incorporating Culturally Relevant Pedagogy and alignment with the Next Generation Science Standards helps to move science teaching toward a practice of inclusion, discussion, and inquiry, which will inevitably lead all students to feeling more of a connection to science and a higher possibility of students going into the sciences as a career. Historically, our BIPOC students have felt a disconnect from science and are currently underrepresented in the scientific community. As science educators we have a responsibility to help guide a generation of innovators who can disrupt that narrative and feel called to challenge inequities in science, in their communities, and in the world. This one unit may not make much of a difference, but it could result in a group of students who have the cultural competence, critical consciousness, and self-assuredness to go into the world and try.

Possible Future Work

As with any unit structured as a storyline, I think the data gathered each year about the direction the students take the unit in will be extremely useful in future planning. With this particular unit, I wanted to ground it more with broad macroscopic concepts that students can connect to what's going on in their world rather than the usual microscopic focus that genetics units can sometimes take on. I think that possible future work could include finding ways to make those microscopic details more relevant and relatable as well while still viewing genetics through a lens of equity and Culturally Relevant Pedagogy. Most obviously, I think that future work could involve looking at every unit in the biology curriculum and seeing ways that race and equity could be more built-in and discussed. I think that as more educators start to look at ways that their curriculum could be more focused on Culturally Relevant Pedagogy, it's imperative that we're given the tools to be able to execute that successfully and tactfully so having professional development and meaningful training around how to have those courageous conversations would be a great direction to go in.

This project also made me think about making the science curriculum more choice-based while also meeting state standards and how districts could go about doing that. I think it would be worth exploring a new model of the science course selection process that would make the journey more equitable by providing more choice. One idea is that all students take a very introductory, year-long science course where each subject (chemistry, biology, physics, and environmental science) is briefly covered over a quarter. After that first year, students would be able to take courses based on what they found interesting - if they found chemistry interesting they could take a cooking and baking class or a forensics class (for example). If they were fascinated with biology they could take animal science or human physiology. Physics could explore astronomy and electricity. I think it would be a neat way to make science more accessible for all students and make it something that they are actually excited about because it is relatable and they chose their interest.

Summary

This project sought to answer the question, *How can science educators create a more equitable science classroom in order to increase engagement among BIPOC students?* Using the curriculum described, students will have opportunities to relate science to themselves and their communities, develop cultural competence and critical consciousness, and practice engaging in argument with evidence while having meaningful, courageous conversations in order to become critical thinkers who are committed to social justice. This section explored the ways in which it is difficult to plan for this, as student voice is a cornerstone of a culturally responsive curriculum. Despite this, with Backward Design and Culturally Relevant Pedagogy it is possible to create a race and discussion based unit that is culturally responsive that is both intentional and meaningful and will help students connect science to their everyday lives.

Sharing this curriculum and literature review with other science educators can allow for more BIPOC students to find connections to science, feel more engaged in the science curriculum, and potentially go into the sciences as a career to be an advocate for scientific and social justice. With many states currently advocating for the privilege to teach students about the ways in which this country is founded on systemic racism, it is clear that as science educators we need to find ways to incorporate this history into our curriculum so we can help guide a generation of students who are critically thinking, science-minded, anti-racist agents of change.

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