Reducing Societal Bias through the Study of Genetics

Unit Title: Reducing Societal Bias through the Study of Genetics

Time Frame: 20 Periods

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Developed for Course Name and Course Code: Biology, Grade 11, University Preparation SBI3U

Strand(s) and Curriculum Learning Expectations Addressed:

Scientific Investigation Skills Strand

SIS.02 · select appropriate instruments and use them effectively and accurately in collecting observations and data (e.g., microscope, laboratory glassware, stethoscope, dissection instruments);
SIS.04 · select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation to communicate scientific ideas, plans, and experimental results (e.g., use characteristics of organisms and the principles and nomenclature of taxonomy to classify organisms; use proper terminology related to organs and tissues);
SIS.05 · locate, select, analyse, and integrate information on topics under study, working independently and as part of a team, and using appropriate library and electronic research tools, including Internet sites;
SIS.06 · compile, organize, and interpret data, using appropriate formats and treatments, including tables, flow charts, graphs, and diagrams;
SIS.10 · identify and describe science- and technology-based careers related to the subject area under study (e.g., biochemist, forester, geneticist, physiotherapist, oncologist, horticulturist).

Cellular Functions Strand

CFV.01 · demonstrate an understanding of cell structure and function and the processes of metabolism and membrane transport;
CFV.03 · demonstrate an understanding of the relationship between cell functions and their technological and environmental applications.
CF1.01 – describe how organelles and other cell components carry out various cell processes (e.g., digestion, transportation, gas exchange, excretion) and explain how these processes are related to the function of organs;
CF1.02 – identify and describe the structure and function of important biochemical compounds, including carbohydrates, proteins, lipids, and nucleic acids;
CF1.06 – illustrate and explain important cellular processes (e.g., protein synthesis, respiration, lysosomal digestion), including their function in the cell, the ways in which they are interrelated, and the fact that they occur in all living cells.
CF3.01 – present informed opinions on advances in cellular biology and possible applications through related technology (e.g., new treatments for cancer; the possibility of producing ethanol as a fuel; the uses of radioactive labelling, fluorescence of genetic material, or simulations of three-dimensional molecular structure);

CF3.03 – analyse ways in which societal needs have led to technological advances related to cellular processes (e.g., document, using newspaper articles, the impact of public awareness on research to detect and treat diseases such as AIDS and hepatitis C).

Genetic Continuity Strand

GCV.01 · demonstrate an understanding of the necessity of meiosis and describe the importance of genes in transmitting hereditary characteristics according to Mendel's model of inheritance;
GCV.02 · perform laboratory studies of meiosis and analyse the results of genetic research related to the laws of heredity;
GCV.03 · outline the scientific findings and some of the technological advances that led to the modern concept of the gene and to genetic technology, and demonstrate an awareness of some of the social and political issues raised by genetic research and reproductive technology.
GC1.01 – demonstrate an understanding of the process and importance of mitosis (e.g., cell division and the phases of mitosis);
GC1.02 – explain how the concepts of DNA, genes, chromosomes, and meiosis account for the transmission of hereditary characteristics from generation to generation (e.g., explain how the sex of an individual can be determined genetically; demonstrate an understanding that the expression of a genetic disorder linked to the sex chromosomes is more common in males than in females);
GC1.04 – explain the process of meiosis in terms of the replication and movement of chromosomes;
GC1.05 – describe genetic disorders (e.g., Down syndrome, cystic fibrosis, muscular dystrophy, fragile X syndrome) in terms of the chromosomes affected, physical effects, and treatment;
GC1.06 – explain, using Mendelian genetics, the concepts of dominance, co-dominance, incomplete dominance, recessiveness, and sex-linkage;
GC1.07 – predict the outcome of various genetic crosses.
GC2.01 – explain the process of meiosis, with reference to a computer simulation or to their own investigations with a microscope (e.g., using slides of grasshopper testis, explain what happens in the first and second stages of prophase and metaphase and anaphase 2 in meiosis);
GC2.02 – solve basic genetic problems involving monohybrid crosses, incomplete dominance, co-dominance, dihybrid crosses, and sex-linked genes using the Punnett method;
GC2.03 – organize data (e.g., in a table) that illustrate the number of chromosomes in haploid cells and diploid cells, and the number of pairs of chromosomes in diploid cells, that occur in various organisms before, during, and as a result of meiosis;
GC2.05 – research genetic technologies using sources from print and electronic media, and synthesize the information gained (e.g., describe the Human Genome Project, transgenics, or the process of genetic screening; list the advantages and disadvantages of cloning or the genetic manipulation of plants).
GC3.01 – summarize the main scientific discoveries of the nineteenth and twentieth centuries that led to the modern concept of the gene (e.g., the discoveries of Hugo de Vries, W.S. Sutton, Thomas Morgan, J. Muller, Barbara McClintock, Rosalind Franklin, James Watson, and Francis Crick);

GC3.02 – describe and analyse examples of genetic technologies that were developed on the basis of

scientific understanding (e.g., the improvement of an experimental procedure to extract DNA from bacterial or plant cells);

GC3.03 – identify and describe examples of Canadian contributions to knowledge about genetic processes (e.g., research into cystic fibrosis) and to technologies and techniques related to genetic processes (e.g., the invention of nuclear magnetic resonance [NMR]).

Diversity of Living Things Strand

DLV.03 · relate the role of common characteristics and diversity within the kingdoms of life (including Eubacteria and Archeabacteria) to the importance of maintaining biodiversity within natural ecosystems, and explain the use of micro-organisms in biotechnology.

DL1.04 – compare and contrast the life cycles of representative organisms from each life kingdom and a representative virus (e.g., draw and label the life cycles of representative organisms, and make a chart comparing the features of the life cycles);

DL1.05 – explain the importance of sexual reproduction (including the process of meiosis) to variability within a population.

DL3.02 – demonstrate an understanding of the connection between biodiversity and species survival (e.g., state the advantages to a population of having genetic variations between individuals – such as the resistance to infection by "new" micro-organisms, the resistance of insects to pesticides, or the resistance of bacteria to antibiotics; explain why some species and not others survive an environmental stress).

Desired Results

Societal bias towards the "other" stems from a lack of knowledge or unfamiliarity with those from different backgrounds than our own. In order to reduce this bias, educators should strive to point out that there is no biological basis for race (Jensen, 2005), while celebrating the cultural and genetic differences between people from different regions and evolutionary adaptations that ensure survival of some individuals within populations.

Genetic anomalies usually result from very small variations in our genetic make up. We are all very much the same. Humans usually have 23 pairs of chromosomes, with slight variations between the 23rd pair of chromosomes in men and women. When chromosomal anomalies occur in the quantity or type of genetic information received, it should be recognized that the amount of genetic variation from what is considered to be the norm can be very minimal. In the case of sickle cell inheritance, the variation is in one base pair change in our DNA resulting in one amino acid change in one of the proteins that produces hemoglobin (Stryer, 1988). Down's syndrome occurs as a result of non-disjunction in which chromosomes forming the 21st pair fail to separate during meiosis (Raven and Johnson, 1992), resulting in a child to be born with three copies of the 21st chromosome rather than the usual two.

Gender and minority bias has been ("Forty years ago, women made up only 3 percent of America's scientific and technical workers" NAS report, 2006) and continue to be ("Among science and engineering PhDs, four

times more men than women hold full-time faculty positions" NAS report, 2006) a major issue in both the physical and natural sciences, ("Women in science and engineering are hindered not by lack of ability but by bias and outmoded institutional structures" New York Times, 2006: September 19) and in academia. Minority groups may be excluded from participation in scientific research due to worldview differences; evidence exists that Aboriginal people are under-represented in science and technology occupations and educational programs due to cultural bias found in science (Canadian Council of Learning, 2007). Other factors that may contribute to the under-representation of minority groups in the sciences include under equipped schools found in minority communities, judgments about ability, number and quality of science and mathematics courses offered and access to resources (NSF, 2007).

My goal in lesson planning is to relate concepts from different fields of scientific research and from different courses in the Ontario high school curriculum. To that end, I have included expectations that have been met from other courses, where appropriate. I have included a number of expectations which can be found in the grade 11 University English curriculum. This comes as a result of my attempts to increase non-fiction writing opportunities in my classes, where appropriate.

I attempt to differentiate my instruction and activities wherever possible. To this end, I often employ 4MAT lesson planning. Rather than go into a detailed explanation of this highly effective method of instruction, based upon brain-based teaching methods, I will direct you to instructional titles such as *Teaching Around the 4MAT Cycle: Designing instruction for diverse learners with diverse learning styles,* by Bernice and Dennis McCarthy (2006).
The benefits of non-fiction writing extend beyond the English classroom and lead to improvements in students' understanding of other curricula. "Within science, people write for many reasons, such as to record data, report findings of experiments, inform others about science topics, and persuade others of the plausibility of their hypotheses. With this understanding, we provide students with opportunities to write for the same reasons that scientists write" (Tower, 2005). This approach has paid off dividends in my science classes.

Unit Description

Executive Summary

Generalizations and misconceptions concerning minority groups in society have often been used as justifications for keeping said groups in their established positions. These disadvantaged groups often include but are not limited to racial and religious minorities, women, and those afflicted with congenital anomalies. The study of genetics is one method through which ignorance and intolerance can be decreased.

Reducing Societal Bias through the Study of Genetics

Lesson 1

Women and those from visible minority groups had traditionally been under-represented or under-acknowledged in the sciences. Students will have an opportunity to investigate this bias through a research based project on a female or visible minority researcher from a field of biology (focusing on, but not limited to, genetic research). The project will allow students to examine the obstacles that some members of society have had to overcome and, in many cases, still encounter in the pursuit of their goals. The project will also require that students provide information on the research performed by the individual that they chose to study and its place in the scope of scientific knowledge.

Lesson 2

Congenital anomalies come in a wide variety and can have a range of effects on individuals afflicted with them. Through the study of karyotypes, inheritance, and the effects of the pre-natal environment on development, students will identify the challenges and issues faced by individuals affected by genetic abnormalities.

Lesson 3

Variations within and between groups of people is commonly explained through the study of inheritance. The inheritance of sickle cell anemia and its prevalence among certain populations will be examined as an adaptation to malarial infections as opposed to the view of sickle cell disease, as a genetic disorder. This will be accomplished through an examination of the populations found in regions where sickle cell anemia is most common and a comparison of this data to rates of malarial infections. The process of sickle cell inheritance and the resistance to malarial infection it grants will provide students with the knowledge to challenge assumptions about populations in which sickle cell anemia is commonly found.

Enduring Understandings / Learning:

Lesson 1:

Students will:

- Learn to work collaboratively.
- Gain knowledge of the accomplishment of scientists/geneticists from under-represented segments of society.
- Develop an understanding of the obstacles encountered by some members of society and the steps they must take to overcome these obstacles in the pursuit of their goals.
- Develop skills that will allow them to overcome obstacles they may encounter in their own lives.
- Develop non-fiction reading and writing skills that will transfer to the enhancement of abilities in other courses.

Lesson 2:

Students will:

- Gain insight into the societal obstacles encountered by individuals with genetic anomalies.
- Empathise with individuals with genetic anomalies.
- Gain an understanding of the causes of genetic anomalies.
- Develop microscope investigation skills
- Develop skills related to diagnosing genetic anomalies.
- Develop research skills.
- Personalize the obstacles encountered by individuals with genetic anomalies.

Lesson 3:

Students will:

- Develop an understanding of the connection between evolutionary adaptations and environmental pressures.
- Develop microscope investigation skills.
- Compare and contrast normal and mutant varieties of cells.
- Develop skill related to the rules governing genetic inheritance.
- Explain the causes of some genetic mutations.
- Develop lifecycle models.
- Understand that genetic variation is fundamental to species survival.

Assessment Tasks

Performance Tasks and Other Evidence That Will Demonstrate the Knowledge and Skills Acquired:

Students will:

- Develop a biography of a scientist/geneticist from an under represented segment of society. A rubric has been included in appendix A, to assist in the evaluation of the expectations.
- Develop a research paper on the obstacles encountered by individuals with genetic anomalies. A rubric has been included in appendix B, to assist in the evaluation of the expectations.
- Develop a model of the lifecycle of the *Plasmodium vivax*. A rubric has been included in appendix C, to assist in the evaluation of the expectations.

A learning skills assessment sheet can be found in the Appendixes. This will allow for the tracking of learning skills through the unit.

Assessment Criteria:

Rubrics have been included in the appendixes.

- Rubric 1 may be used to evaluate the students' biography of a scientist form an under-represented segment of society (lesson 1).
- Rubric 2 may be used to evaluate the students' research paper on obstacles that must be overcome by an individual with a genetic anomaly (lesson 2).
- Rubric 3 may be used to evaluate the students' development of a model of the *Plasmodium vivax* lifecycle (lesson 3)

A general learning skills assessment sheet has been added and may be used to assess student learning skills throughout the unit. Teachers may use this sheet to tract learning skills throughout the unit. This sheet has been kept very general and may be used in other units as well.

Unit Planning Notes

Prior Learning Necessary (if any):

Students should be familiar with cell division and the fact that genetic information is passed from parental cells to their progeny. These concepts are covered in SNC1D.

Preparation Notes (if any):

- Develop a list of scientist/geneticists from under-represented segments of society
- Provide students with information of biography writing and citation procedures
- Video equipment (DVD player, VCR)
- Preview video clips from one or more of the following films:
  i. *Lorenzo's Oil* (Adrenoleukodystrophy or ALD)
  ii. *My Left Foot* (Cerebral palsy) may need to edit for language
  iii. *Mask* (Craniophyseal dysplasia)
  iv. *Duo* (Down's syndrome)
  v. *The Station Agent* (Achondoplasia)
  vi. *Jack* (Werner syndrome)

  Take into consideration the maturity level of the class, and preview the film clips for overall appropriateness.

- Personal stories (see links in lesson plan)
- Class set of microscopes
- Slides of cells undergoing meiosis
- Karyotypes (see links in lesson plan)
- Blank world maps (see link in lesson plans)
- Slides of sickle shaped red blood cells
- Slides of normal red blood cells
- Models of DNA
- Plasticine
- Scissors
- Coloured paper
- Coloured pencils

Learning Plan

Lesson 1: Reducing gender and cultural bias in the science classroom.

1. EXPERIENCING

I. Engage the students in a new experience :

a. Place one or more of the following quotations on the chalkboard or overhead (BLM 1)

- "Women are more likely to have their research published if the referees who review their work are unaware of their gender."
  - *New Scientist*, January 2008
- "Troubling performance gaps exist between Hispanic and African American students and their white peers, and also across socioeconomic divisions. These achievement gaps continue to show up in grades, dropout rates, advanced science course selection, and standardized test scores. African American and Hispanic science students continue to underperform compared to white students, and poor school districts underperform compared to affluent ones.
  - *Science Teacher*, March 2007
- "A number of factors contribute to the high attrition for women (and under-represented minority men) in science."
  - Office of the Dean of the College at Brown University, 2005
- "If academia is to offer varied role models and perspectives for a diverse population of students, it must become more welcome to women and ethnic minorities."
  - *Nature*, March 2007

II. Reflection and analyses of the experience:

- **a.** Have the students reflect on the quotations.
- **b.** Students should be directed to form small discussion groups or may reflect on the quotations on their own.
- **c.** Questions to initiate discussion (BLM 2)
  - Why may gender bias exist in peer reviewed journals?
  - Why do you think gaps in achievement exist?
  - What could be done to improve or change the achievement of minority groups?
  - What may be some of the causes of a high drop out or switch out rate among women and men from under-represented minority groups?

2. CONCEPTUALIZING

III. Integration of the experience:

- **a.** Have the students read the following articles on gender gaps and bias in sciences.
  - The gender gap in science
    http://chronicle.com/jobs/2001/10/2001102201c.htm
  - Beyond the glass ceiling
    http://www.nature.com/naturejobs/2007/070705/pdf/nj7149-098a.pdf
- **b.** Have students reflect on the readings and answer the following questions (BLM 3)
  - Why might science be viewed as a "male career"?
  - Is gender and visible minority bias in the sciences a societal issue or something that should be handled by academic institutions?
  - What types of accommodations might encourage more women and visible minorities to enter scientific fields?
  - Is there blatant discrimination against women and visible minorities entering the science or is there more subtle discouragement?
  - What might subtle discouragement look like?

IV. Teaching and learning of concepts and skills:

- **a.** Students should have an opportunity to write a biography on a scientist, preferably from an under-represented segment of society (Rubric 1).
- **b.** The students may be encouraged to discover their own "lesser" known scientists and should be directed to try to select scientists from under-represented segments of society, preferably Canadian but not necessarily so.
- **c.** Many of these scientists are currently practicing in their fields and may be interested in answering biographical questions through e-mail correspondence.

3. APPLYING

V. Practice of newly acquired skills:

- **a.** Students should include standard biographical information including: birth date, and where they studied.

b. Students should be given an opportunity to brainstorm on related questions that they would ask their chosen scientist.

c. Possible questions include:

- What is their gender and/or ethnic background?
- What made them decide to pursue scientific research?
- What role did their gender or ethnicity play in the career?
- What obstacles did they have to overcome in the pursuit of their career?

VI. Application of concepts:

a. Students should research the protocols followed in one of the experiments performed by their selected scientist (BLM 4).

b. The experiments need not be completely understood as many of the concepts may be beyond the level of an SBI3U student.

c. Students should cover the basics of the research performed by their selected scientists, these include:

- The focus of their research.
- Their greatest accomplishments.
- How their accomplishments contributed to scientific knowledge and/or to improving the quality of human life?
- What extensions to their research have been or may be performed?
- How would the student extend or improve upon their research?

4. CREATING

VII. Analyses of newly acquired concepts:

a. Students should present their biography

- The presentation may be in the form of a poster presentation, if the students choose to present a poster they may use BLM 4 as a template upon which to base their headings.
- Students may choose to focus on the obstacles that their chosen scientist had to overcome in pursuit of their career.
- Extensions to the presentations may include the use of school showcases in which the poster presentations can be exhibited to the school.

VIII. Extension of newly acquired concepts to more complex situations:

a. Students should develop a list of problems encountered by women and under-represented segments of society in the pursuit of careers in the sciences (BLM 5).

b. Students should then develop a list of possible solutions that can be pursued by high schools, academic institutions, governments, science and science education organizations, and through self advocacy by individuals themselves

Reducing Societal Bias through the Study of Genetics

Lesson 2: Congenital anomalies, the study of karyotypes, and issues faced by individuals affected by genetic abnormalities.

1. EXPERIENCING

I. Engage the students in a new experience :

a. Have the students view a portion of a film in which genetic anomalies play a part.

b. Examples include:

- *Lorenzo's Oil* (Adrenoleukodystrophy or ALD)
- *My Left Foot* (Cerebral palsy) may need to edit for language
- *Mask* (Craniophyseal dysplasia)
- *Duo* (Down's syndrome)
- *The Station Agent* (Achondoplasia)
- *Jack* (Werner syndrome)

Take into consideration the maturity level of the class, and preview the film clips for overall appropriateness.

II. Reflection and analyses of the experience:

a. Break students into small groups.

b. Have the students to discuss what they understand about genetic anomalies (BLM 6).

c. Students may be prompted to describe the visible symptoms and societal obstacles that individuals exhibiting genetic anomalies must overcome.

2. CONCEPTUALIZING

III. Integration of the experience:

a. Students should read personal stories from the following sources:

i. Down's syndrome (http://www.cdss.ca/site/resources/personal_stories/index.php)

ii. Cerebral palsy (http://www.kidshealth.org/teen/diseases_conditions/personal_stories/keith_story.html)

iii. Cystic fibrosis (http://www.kidshealth.org/teen/diseases_conditions/personal_stories/grant.html)

b. Students should have the opportunity to view slides of cells undergoing meiosis and identify and draw the stages of meiosis.

IV. Teaching and learning of concepts and skills:

a. Students should be introduced to the concepts of karyotypes and karyotype/chromosome mapping.

b. Students should be shown how a karyotype/chromosome map is made (BLM 7).

c. Students should be taught about the structure of chromosomes, the stages of meiosis and the crossing over of homologous chromosome segments during prophase I of meiosis.

d. An understanding of these concepts will become very important when the students later come up with plausible explanations for causes of genetic anomalies.

3. APPLYING

V. Practice of newly acquired skills:

a. Students should be given an opportunity to identify differences between:

i. normal male and female karyotype maps

- http://k-12.pisd.edu/currinst/science/Genetic/Karyo-norm.htm
- http://bluehawk.monmouth.edu/~bio/images/Karyotype/normalmalefinished.jpg

ii. karyotypes from individuals with genetic anomalies

- http://k-12.pisd.edu/currinst/science/Genetic/Karyotype-Chrom-Disorders.htm

VI. Application of concepts:

Students should be aware of the basic structure and role of chromosomes before continuing.

a. Students should be broken up into groups.

b. The groups will be given samples of randomized karyotypes of individuals with normal chromosome numb male and female) and karyotypes from individuals with genetic anomalies.

i. These may be found at

- http://www.biologycorner.com/worksheets/karyotype/chromosomestudy-teacher.html
- http://bluehawk.monmouth.edu/~bio/karyotypes.htm

c. Students should be given class time to cut out, organize according to karyotype mapping rules, and glue the chromosomes on a separate sheet of paper. This will provide an opportunity for them to produce a variety karyotype maps that can be compared to each other.

d. The final products may be set on poster paper and displayed in the classroom.

4. CREATING

VII. Analyses of newly acquired concepts:

a. Students may be given an opportunity to research the:

i. causes

ii. symptoms

iii. treatments and/or prevention of a genetic anomaly.

b. This information should augment research into the societal challenges and triumphs encountered by indi with genetic anomalies (BLM 8).

VIII. Extension of newly acquired concepts to more complex situations:

a. Students may be directed to write a personal story related to obstacles they have had to overcome in the lives.

i. Students may be prompted to compare their own challenges to those that have been successfully overcome by individuals with genetic anomalies (BLM 9).

b. Students may be prompted to write a research paper on obstacles that an individual with a genetic anom have to overcome in the students own school or neighborhood (Rubric 2).

c. Students may be prompted to write a letter to a school trustee or principal concerning obstacles to learni individuals with genetic anomalies may have to overcome in their own school.

a. Students should be given an opportunity to compare and contrast sickle and normal red blood cells. Students should compare:
- **i.** the shape of the cells
- **ii.** their ability to carry oxygen
- **iii.** the amino acid sequence of their Hb molecules
- **iv.** their relationship to malarial infections

I. Application of concepts:

a. Students should work in small groups to design models of the malaria causing *Plasmodium vivax* life cycle.
- **i.** The models may be drawn on paper
  or
- **ii.** Actual models of mosquitoes, normal red blood cells, sickle red blood cells, plasmodia, various developmental stages of *Plasmodium vivax*, and human blood vessels may be designed and constructed by either individual students or small groups of students (Rubric 1).

4. CREATING

II. Analyses of newly acquired concepts:

a. Students should now have the background knowledge to begin to synthesize many of the concepts covered in the previous steps.
- **i.** Students may be prompted to develop a hypothesis as to why regions in which people have higher than usual rates of sickle cell anemia coincide with those regions in which rates of malaria are higher than normal (BLM 10).
- **ii.** Students may develop hypotheses concerning the genetic mutation found in the DNA of individuals and its connection to the formation of sickle cells.
- **iii.** Students may develop hypotheses as to why the mutated form of hemoglobin found in those with sickle cell anemia provides protection from *Plasmodium vivax* infection.

III. Extension of newly acquired concepts to more complex situations:

a. Students should now be equipped with the knowledge to question genetic variation between people from different regional backgrounds.

i. If the inheritance of sickle cell anemia is taught as an adaptive consequence through which those with the trait in regions with high rates of malaria have a genetic advantage over those without the trait, students may begin to observe genetic (and possibly cultural) variations as adaptations to environmental pressures rather than simply as "differences" between people.

ii. Students should discover that variation is the key to species survival and that variations between populations of humans occur as a result of environmental pressures and the variation in the incidence of alleles in different human populations.

a. Extensions to additional topics related to human genetic environmental adaptations include:

i. The vitamin D theory of variation of melanin concentrations in epidermal cells.

ii. Genetic adaptations to high altitude living among people from Andean and Himalayan regions.

iii. Genetic adaptations to cold climates found in people from Arctic Regions.

iv. Dietary adaptations found in peoples from a wide range of environmental regions.

Attachments

Rubric1: Biography of a scientist from an under-represented segment of society
BLM 1: Quotes to initiate thinking
BLM 2: Prompts for responses to quotes
BLM 3: Interactive notes on readings
BLM 4: Biography outline
BLM 5: Problem- solution sheet
Rubric 2: Research paper on obstacles that must be overcome by an individual with a genetic anomaly
BLM 6: Genetic anomalies KWHL chart
BLM 7: Karyotype mapping
BLM 8: Research into a genetic anomaly
BLM 9: Comparison organizer for personal response
Rubric 3: Development of a model of the *Plasmodium vivax* lifecycle
BLM 10: Percentage of Persons with Hb^S by Country
BLM 11: Rate of malarial infection per 100 000 individuals in the population
BLM 12: Sickle cell trait distribution
BLM 13: Distribution of malaria
BLM 14: Normal red blood cells
BLM 15: Sickle shaped red blood cells
BLM 16: Sickle cell trait inheritance
BLM 17: Plasmodium life cycle
BLM 18: The mutation that results in sickle cell formation
BLM 19: Hypothesis development

Appendix A: Learning Skills
Appendix B: References

Other Possible Course Applications

Writing extensions related to the ENG3U curriculum, with the appropriate expectations have been included. Expectations related to mapping in the CGU4U and CGW4U courses have been included.