PLTW BE Science Framework

PLTW Course: Biotechnical Engineering (BE)

Science Strands being addressed: **Strand 1: Nature of Science and Engineering**
Strand 4: Life Science

Science Sub-strands being addressed: Sub-strand 3: Interactions Among Science, Technology, Engineering, Mathematics and Society, Sub-strand 4: Human Interactions with Physical Systems

Science Standards being addressed: 9.1.3.3 & 9.4.4.1

Overview:

Science Standards and Benchmarks: 9.1.3.3, 9.1.3.3.2, 9.1.3.3.3, 9.4.4.1.1

Standard 9.1.3.3: Science and engineering operate in the context of society and both influence and are influenced by this context.

Benchmark 9.1.3.3.1: Describe how values and constraints affect science and engineering.
For example: Economic, environmental, social, political, ethical, health, safety and sustainability issues.

Benchmark 9.1.3.3.2: Communicate, justify and defend the procedures and results of a scientific inquiry or engineering design project using verbal, graphic, quantitative, virtual or written means.

Benchmark 9.1.3.3.3: Describe how scientific investigations and engineering processes require multi-disciplinary contributions and efforts.
For example: Nanotechnology, climate change, agriculture or biotechnology.

Standard 9.4.4.1: Human activity has consequences on living organisms and ecosystems.

Benchmark 9.4.4.1.1: Describe the social, economic and ecological risks and benefits of biotechnology in agriculture and medicine.

Correlation to AAAS Atlas (Benchmarks for Science Literacy):
MN 9.1.3.3.1, MN 9.1.3.3.2, 9.4.4.1.1
1C/H5a*, 1C/H5b*, 1C/H6ab, 1C/H8, 1C/H10**, 1C/H11**, 3B/H2, 3CH1, 1C/H12**, 3C/H6**, 12D/H7*, 1C/H4, 3C/H3*, 3C/H4, 3C/H5, 12E/H6b, 12FSPSP6, 12FSPSP6.1, 12FSPSP6.2, 12FSPSP6.3, 12FSPSP6.4, 12GHNS1, 12GHNS1.3, 12ASI1, 12ASI1.6, 12EST1, 12EST1.5, 12EST2, 12EST2.1, 12GHNS1, 12GHNS1.1, 12FSPSP6, 12FSPSP6.3, 12FSPSP6.4, 12FSPSP6.5, 12GHNS3, 12GHNS3.3

MN 9.1.3.3.1 Correlation:

- Scientists' nationality, sex, ethnic origin, age, political convictions, and so on may incline them to look for or emphasize one or another kind of evidence or interpretation. 1B/H8** (SFAA)
- Progress in science and invention depends heavily on what else is happening in society. 1C/H3a
- Current ethics in science hold that research involving human subjects may be conducted only with the informed consent of the subjects, even if this constraint limits some kinds of potentially important research or influences the results. 1C/H5a*
- When applications of research could pose risks to society, scientists' decisions to participate in that research are based on personal as well as professional ethics. 1C/H5b*
- Scientists can bring information, insights, and analytical skills to bear on matters of public concern. Acting in their areas of expertise, scientists can help people understand the likely causes of events and estimate their possible effects. 1C/H6ab
- Funding influences the direction of science by virtue of the decisions that are made on which research to support. Research funding comes from various federal government agencies, industry, and private foundations. 1C/H8
- Because science is a human activity, what is valued in society influences what is valued in science. 1C/H10** (SFAA)
- The direction of scientific research is affected by informal influences within the culture of science itself, such as prevailing opinion on which questions are most interesting or which methods of investigation are most likely to be fruitful. Elaborate processes involving scientists themselves have been developed to decide which research proposals receive funding, and committees of scientists regularly review progress in various disciplines to recommend general priorities for funding. 1C/H11** (SFAA)
- The value of any given technology may be different for different groups of people and at different points in time. 3B/H2
- Social and economic forces strongly influence which technologies will be developed and used. Which will prevail is affected by many factors, such as personal values, consumer acceptance, patent laws, the availability of risk capital, the federal budget, local and national regulations, media attention, economic competition, and tax incentives. 3C/H1

MN 9.1.3.3.2 Correlation:

- The dissemination of scientific information is crucial to its progress. Some scientists present their findings and theories in papers that are delivered at meetings or published in scientific journals. Those papers enable scientists to inform others about their work, to expose their ideas to criticism by other scientists, and, of course, to stay abreast of scientific developments around the world. 1C/H12** (SFAA)
- The human ability to influence the course of history comes from its capacity for generating knowledge and developing new technologies—and for communicating ideas to others. 3C/H6** (BSL)
- Use tables, charts, and graphs in making arguments and claims in oral, written, and visual presentations. 12D/H7*

MN 9.1.3.3.3 Correlation:

- Science disciplines differ from one another in what is studied, techniques used, and outcomes sought, but they share a common purpose and philosophy, and all are part of the same scientific enterprise. Although each discipline provides a conceptual structure for organizing and pursuing knowledge, problems are studied by scientists using information and skills from many disciplines. Disciplines do not have fixed boundaries, and it happens that new scientific disciplines are being formed where existing ones meet and that some sub-disciplines spin off to become new disciplines in their own right. 1C/H4

MN 9.4.4.1.1 Correlation:

- In deciding on proposals to introduce new technologies or curtail existing ones, some key questions arise concerning possible alternatives, who benefits and who suffers, financial and social costs, possible risks, resources used (human, material, or energy), and waste disposal. 3C/H3*
- The human species has a major impact on other species in many ways; reducing the amount of the Earth's surface available to those others species interfering with their food sources, changing the temperature and chemical composition of their habitats, introduce foreign species into their ecosystems, and altering organisms directly through selective breeding and genetic engineering 3C/H4
- Human inventiveness has brought new risks as well as improvements to human existence. 3C/H5
- Suggest alternative trade-offs in decisions and designs and criticize those in which major trade-offs are not acknowledged. 12E/H6b

Correlation to NSES (National Science Education Standards):

MN 9.1.3.3.1 Correlation:

- Science and technology in local, national, and global challenges (12FSPSP6)
    - Science and technology are essential, but, alone, can only indicate what can happen, not what should happen (12FSPSP6.1)
    - Understanding the basics of science and technology should precede debate about related practical and ethical challenges (12FSPSP6.2)
    - Progress in science and technology can relate to social issues/challenges (12FSPSP6.3)
    - Individuals and society must decide on proposals of new research/technologies (12FSPSP6.4)
- Science as a human endeavor (12GHNS1)
    - Scientists are influenced by social, cultural, and personal beliefs (12GHNS1.3)

MN 9.1.3.3.2 Correlation:

- Abilities necessary to do scientific inquiry (12ASI1)
    - Communicate a scientific argument (12ASI1.6)
- Abilities of technological design (12EST1)
    - Communicate the problem, process, and solution (12EST1.5)

MN 9.1.3.3.3 Correlation:

- Understanding about science and technology (12EST2)
    - Scientists in different disciplines use different methods (12EST2.1)
- Science as a human endeavor (12GHNS1)
    - Individuals and teams contribute to the scientific enterprise (12GHNS1.1)

MN 9.4.4.1.1 Correlation:

- Science and technology in local, national, and global challenges (12FSPSP6)
    - Progress in science and technology can relate to social issues/challenges (12FSPSP6.3)
    - Individuals and society must decide on proposals of new research/technologies (12FSPSP6.4)
    - Humans have a major effect on other species (12FSPSP6.5)
- Historical perspectives (12GHNS3)
    - Some advances in science and technology have important and long-lasting effects (12GHNS3.3)

Essential Understandings/Big Ideas:

- Science and technology do not stand alone. They are influenced by the values, attitudes and norms of the society in which they occur.
- Science is influenced by society, and in turn, society is influenced by science.
- Communication of scientific findings is therefore a critical component of scientific research, and must be done using a variety of methods in order to be as clear as possible about the outcomes of findings.
- Communication also fosters collaboration between the different disciplines of science and engineering, which allows for cooperation among these disciplines in finding the best possible solutions to benefit the needs of society. Biotechnology, for example, is one field that requires knowledge and expertise in several disciplines and is also heavily influenced by they ethics, morals, values, and needs of society.

Biotechnology is a relatively new field of inventions and innovations that is advancing rapidly and has tremendous implications for the future of all living things. Biotechnically engineered products have applications in the fields of agriculture, the environment, and medicine, just to name a few. These applications, processes, and inventions are being funded by private and non-profit organizations. Thus, industry and the private sector must work together toward the development of biotechnically engineered products. In addition, bioethical issues are inherent in technological advancements and have changed the choices society must make. Clearly communicating scientific results and the risks and benefits of biotechnical products is necessary so that an informed public can make sound decisions regarding possible solutions to their needs.

Everything that a human develops and/or does has both benefits and consequences. This applies to biotechnology as well as other areas. The benefits and consequences can impact social, economic and ecological levels within all cultures. Some biotech applications might make medical care more affordable, other times only the rich can afford the treatment. Biotechnical applications can also have a long-term effect on the environment. What seems harmless may lead to the extinction of a species or a dramatic change in climate. But, scientists can also use their knowledge of biological systems to repair environmental damage or replace current technologies with those that are more sustainable and friendly to the environment. Whenever biotechology is utilized, engineers must consider the ecological risks and benefits of that application or product in addition to the social and economic consequences.

What should students know and be able to do [at a mastery level] related to these benchmarks?

Students should be able to:

- Describe how values, ethics, and constraints affect science and engineering.
- Identify the economic, environmental, social, political, ethical, health, safety or sustainability issues involved with a particular research or engineering endeavor.
- Understand that technology in the life sciences cannot be studied without considering the impact of new technologies and the potential to benefit or harm living systems.
- Describe the influence of the financial sector on science and engineering.
- Communicate, justify and defend the procedures and results of a scientific inquiry or engineering design project using verbal, graphic, quantitative, virtual or written means.
- Understand that scientific investigations and engineering processes require multi-disciplinary contributions and efforts.
- Identify the disciplines involved in an engineering design project and how they are involved with the design.
- Understand that the fields of biotechnology are interconnected by the common elements of living organisms.
- Describe the social, economic and ecological risks and benefits of biotechnology in agriculture and medicine.

Misconceptions:

Student Misconceptions

- The only constraint in science research and engineering is money.
- Societal values are universal.
- Scientists and engineers are always neutral and are not influenced by social, cultural, and personal beliefs.
- A “right” opinion exists for every controversial subject. Students should know that many people have different opinions and they should listen carefully to those other viewpoints.
- Communication of scientific findings or an engineered product is best accomplished only through written means. Students underestimate the value of models, graphs, diagram, and other visuals.
- The boundaries between the different scientific and engineering disciplines are fixed and do not overlap. Thus, all endeavors can be categorized under one specific discipline.
- Purchasing choices do not affect what products are available and how they are made or grown. Students should be mindful of the way their purchases can effect the environment.

For example by purchasing vehicles that have poor fuel economy it encourages auto-makers to make vehicles that have poor fuel economy.
- An engineered product only affects the immediate user or consumer with only short-term consequences.
- Technology always improves human existence.
- Genetically modified organisms are “bad”.

Teacher Resources:

Teacher Notes

Unit 2 best addresses these standards, and in particular, benchmarks 9.1.3.3.1, 9.1.3.3.3, and 9.4.4.1.1. The two lessons in this unit allow students to investigate the history and ethics of biotechnology.

Within these lessons, the activities that easily apply to these standards are the following.

- **Project 2.1.1 Biotechnology Timeline WebQuest.** This project uses a WebQuest approach as students research one of the milestones in the evolution of biotechnology from the event, people, or idea listing. After completing the research, students prepare timeline cards that are used in crafting the final timeline and allow them to make connections between the different scientific and engineering disciplines.
- **Activity 2.1.2 Gen Diagram Research.** The students investigate a major industry or profession that utilizes genetic technology to some degree. They then create a PowerPoint presentation that will communicate their research to the class.
- **Activity 2.1.3 Biotechnology Stock Portfolio.** The students research companies within NASDAQ and choose two or more biotechnology companies (in nutriceuticals, biopharmaceuticals, etc.) that will yield the most money on the stock market. This allows students an opportunity to become familiar with the current technologies in the biotechnology industry and what types of local, state, national and global events can affect the financing and success of biotechnology companies. The students compile their research and results in a portfolio that shows what they learned.
- **Activity 2.2.1Walk a Mile in Everyone’s Boots.** In this bioethics investigative activity, students read a scenario dealing with umbilical cord blood and tissue. Students are then assigned specified roles of people or groups that may have a contributing viewpoint based on differing values and morals. The students research these roles and try to think about the situation from the point of view of their assigned role. The activity concludes with the students discussing the scenario and writing a reflection.
- **Project 2.2.2 Bioethics-Beat on the Street.** Students design and conduct a public opinion survey about genetically modified organisms. Tasks include setting an objective (hypothesis) regarding what they want to discover, designing an unbiased survey, collecting responses, and summarizing their results in a report which communicates the purpose, methodology, and results of their investigation.

The biotechnology timeline, “Gen Diagam”, and role-play activities are set up as jigsaw activities - students are expected to share what they learned so that the class will have a complete picture of all of the disciplines, factors, or constraints involved. During these activities, it is important that the teacher monitors students' research and progress. If not carefully monitored, the students can go off on irrelevant tangents with their research. It also helps to have very clear expectations for the finished product as they will use that to guide their research.

The stock portfolio activity, if not done properly, can devolve into a money making contest, and the students lose track of what they are supposed to learn. To keep the students on track, give them a list of companies that have a good financial history, are usually in the news, or are coming out with new products fairly regularly. Also, have a list of daily questions that students need to answer about their company when they are researching daily news. Limit daily time on this activity to a few minutes per day.

With bioethics activities, it is also helpful to scaffold the lesson with some general background information about values and beliefs, as well as the topic for discussion. One resource which can help is a lesson titled *Positions, Beliefs, and Values* from the University of Utah's Genetic Science Learning Center website:
(http://teach.genetics.utah.edu/content/tech/genetherapy/positions.html).

This lesson helps students to understand that beliefs and values influence one's position on controversial topics (such as gene therapy). Students have the opportunity to form their own opinion about gene therapies, examine the personal beliefs that shape their opinions, and determine the values that underlie their personal beliefs about gene therapy. A good introduction for genetically modified organisms and all of the societal issues involved is the NOVA/Frontline special report, *Harvest of Fear*, which also has a companion website:
(http://www.pbs.org/wgbh/harvest/).

Almost all of the activities and projects in the Biotechnical Engineering curriculum require students to communicate and justify their results or design proposals through either written, oral, or graphical means, which addresses benchmark 9.1.3.3.2. The following activities provide a means for meeting this benchmark. Several also meet additional benchmarks within these standards.

- **Activity 1.1.3 Instrumentation Calibration.** Student teams test pipettes for accuracy and precision to determine if they are calibrated by designing their own experimental procedure, creating Excel spreadsheets to collect data, and analyzing the results with statistics and graphs.
- **Activity 3.1.2 Rapid Pathogen Identification.** Students investigate a mock disease outbreak to determine the cause, treatment, and prevention methods. Supplied with pathology reports and DNA sequence data, students hypothesize about which pathogens are responsible for the outbreak, draw a flow chart identifying the paths of infection, and write a final report in which they justify their diagnosis.
- **Activity 3.1.7 Designer Genes: Industrial Applications.** The students are asked to identify a problem and design a solution which will "improve the human condition" using fluorescent proteins and gene modification. Students create a PowerPoint with images and text to communicate their conceptual model and explain how their design will solve the problem.

- **Activity 4.1.1 Fermentation Instrumentation, Activity 4.1.2 Optimizing Yeast Fermentation, and Project 4.1.3 Fueled by Fungi.** These three interrelated activities are part of an overarching project that requires students to research fermentation, develop a method to test and measure rates of fermentation, optimize reaction rates, and build a car that is fueled by fermentation. They then write a final report that explains the details of their car design, justifies their modifications, and explains their test results.
- **Project 4.1.4 Phyto-engineering.** Students research phyto-engineering, design and conduct a phyto-engineering experiment, and orally present their results to the class. Students must also document all of their work in their engineering notebook.
- **Problem 4.1.5 What's Eating You.** Student teams design an experiment to test the effectiveness of oil eating bacteria on oil that has spilled into the ocean by writing a design brief that explains the problem, identifies the solution expectations and the degree to which that solution will be realized, and lists any appropriate project constraints.
- **Activity 4.1.8 Aquaponics Final Analysis.** Student teams research, design, build, and monitor their own aquaponics system, then communicate their design and test results by completing written documentation in their engineering notebook, generating graphs to display their data, and giving an oral presentation with a visual component.
- **Project 5.2.3 Material Properties of Joints.** Students design, construct a physical model, and evaluate a joint replacement.
- **Project 5.3.4 The Beat is On.** Students discover the significance of electrical impulses for a cardiac cycle, then design and create a 3D model of a portable ECG monitor. Documentation includes sketches of the final product and journal notations of challenges during the building phase of the 3D model. Students will present their model in a oral presentation, providing the pros and cons of their design and identifying one product failure case involving ECG monitors.

Additional Instructional Resources

These resources provide additional instructional tools and up-to-date news regarding biotechnology applications that can be used within these lessons.

- BEEP (BioEthics Education Project) http://www.beep.ac.uk/content/15.0.html
- BIO (Biotechnology Industry Organization) http://www.bio.org/
- Science Daily Biotechnology News
  http://www.sciencedaily.com/news/plants_animals/biotechnology/

There are several case studies available online which allow students to investigate the values, ethics, and economics of biotechnical, scientific, and engineering products and issues. Below is a list of several website that may be used to supplement instruction for these standards.

- National Center for Case Study Teaching in Science
  http://sciencecases.lib.buffalo.edu/cs/.
- McGraw Hill General & Human Biology Bioethics Case Studies
  http://www.mhhe.com/biosci/genbio/olc_linkedcontent/bioethics_cases/.

- Vanderbilt University Center for Ethics
  http://www.vanderbilt.edu/CenterforEthics/cases.html
  http://sciencecases.lib.buffalo.edu/cs/ .
- Biotethics at Iowa State
  http://www.bioethics.iastate.edu/classroom/case_studies.html.
- NIH Bioethics Resources on the Web: http://bioethics.od.nih.gov/.
- HHMI Bioethics resources: http://www.hhmi.org/coolscience/resources/SPT--AdvancedSearch.php?Q=Y&G67=123&ST=Advanced&RP=100&G5=1&sort=title

New Vocabulary

- bioethics - The study of the ethical and moral implications of new biological discoveries and biomedical advances, as in the fields of genetic engineering and drug research.
- constraints - Limitations to a project or procedure. These may be based on physical means or ethical means.
- discipline - A branch of instruction or learning, such as history, biology, chemistry, physics, or mathematics.
- graphic - A visual presentation such as a poster, diagram or model.
- qualitative - Referring to a measure that does not involve "hard" numbers. Examples may include beautiful, healthy, etc.
- quantitative - Referring to measurement and numbers.
- values - The ethical basis of a society. Items such as honesty, motivation.
- verbal - An oral presentation of research results.
- virtual - Generally refers to electronic presentation and/or simulation.
- written - Words used to describe a project, procedure, experiment, etc. such as in a written report.

Vignettes:

Vignette #1

This is a common conversation that happens during the biotechnology timeline activity. In this activity the students learn how past discoveries lead to modern discoveries.

Student: I am having difficulty understanding why this particular event is important to biotechnology.

Teacher: It is important to look for connections. Can you think of any technologies or concepts that would not be possible if not for this event?

Student: Well... I suppose that DNA would not have been discovered.

Teacher: Wow! That sounds very important. Can you think of any more?

Vignette #2

In this vignette the teacher is helping a student understand how advanced technologies can benefit people around the world.

Student: While I was researching genetically modified foods, I found out that farmers in the Philippines are growing genetically engineered rice called Golden Rice. Wouldn't that be more expensive than regular rice?

Teacher: Perhaps, but are there any benefits to growing Golden Rice?

Student: Well, the article said that children have to get regular checkups and vitamin-A supplements, but that the Golden Rice can help supply the vitamins the kids need to be healthy. Rice normally has no vitamin-A, but it is staple food for the Filipinos. So, I guess a benefit would be that children can get what they need from their food rather than having to get supplements from the doctor. That might be less expensive, too.

Teacher: Are there any risks, besides the cost of having to buy the genetically engineered Golden Rice seed?

Student: I 'm not sure. Maybe the gene they inserted to make the vitamin A-could contaminate other crops or wild rice if cross-pollination occurs, but I don't know if that would be harmful. I will have to research that some more.

Assessments:

Assessment Methods

2.1.1 Assessment

- Using 3 X 5 index cards, create a title (include appropriate year) and write a concise paragraph on the impact of each milestone. When the completed timeline is prepared, determine three personal milestone dates, and add them to the timeline. Reflect on the historical knowledge you have gained by responding to the Student Reflection prompt in their engineering notebook. (Time line is evaluated by the BE rubric for this project found in the curriculum.)
- Relevant conclusion questions 2.1.1
  - How do innovations build on previous innovations?
  - What trend do you observe in the number of biotechnical events in recent years? Explain what you believe has created the observed trend.
  - What do you project will be the rate of innovations in the future?

2.1.2 Assessment

- In this activity, students pair up and choose a focus topic from a list of industries and find as much information as they can in order to link the focus topic to the application of genetics technology. The students must include the following information: the historical beginnings of this application (the students may want to refer back to the Biotechnology Timeline they completed in Project 2.1.1 Biotechnology Timeline WebQuest), examples of the various professions involved and the education each of these professions requires, predictions of what the future might bring as it relates to genetic technology definitions of important terms related to the focus topic.
- Relevant conclusion questions 2.1.2
  - How are industries within biotechnology interconnected?
  - What are some fundamental concepts that join the major industries in biotechnology?
  - Which area of biotechnology has the biggest impact on our everyday lives?
  - Explain how the primary cause for the impact is significantly different from the other areas of biotechnology.
  - Based on your research, predict the biotechnical industry that will have the biggest impact in the future and explain your reasoning.

2.1.3 Assessment

- Students research various biotechnology companies and find biotech stock analyst reports. Students then choose at least two companies in which to invest and list (in their engineering notebook) the following properties for each: the name of company with stock symbol, industry, location of the company's headquarters, products, stock history and reason for selection. The students then invest $10,000 of imaginary money in their companies and track their progress over two weeks in their engineering notebook. The students produce a written report outlining their procedure, rationale for investing in these companies, the investment results and explanation for increases and decreases in stock value, and what they have learned about the connection between financial markets, world news, and the biotechnology industry. This report is evaluated with the project 2.1.3 biotechnology stock portfolio report rubric included with the BE curriculum.
- Relevant Conclusion Questions 2.1.3
  - How do financial markets influence the direction of scientific research and ultimately society?

2.2.1 Assessment

- The students read a case study in which a patient may be required by law to donate their child's umbilical cord blood for research and other possible uses in the future. The students are then assigned roles of various people or groups that may have an opinion on the matter. The students have a group discussion, exploring the opinions, beliefs, and values of each stakeholder.
- Relevant conclusion questions 2.2.1
  - It has been stated that some engineers do not consider the ramifications of their work, for better or worse. Why is it important to consider the bioethical issues of technological advancements?

- Why is it important to be open to different perspectives?
    - How is policy developed regarding controversial issues involved in biotechnology research?

2.2.2 Assessment

- Student teams will prepare a report that outlines and interprets the result of their survey on GMOs.
- The report must be three pages or fewer, excluding the results of your survey including the following information; title, objectives of survey, questions asked and results.
- Students will then discuss their results and relate them to the objectives that were stated in during planning along with any unexpected findings that they discovered. They will include their opinion on some questions based on your findings.
- Relevant Conclusion Questions 2.2.2
    - How does public perception of GMOs differ by age, religion, or gender?
    - What type of patterns did you notice concerning the answers provided by the various participants? In other words, were there patterns specific to age, religion, or gender?
    - Why is a large sample size critical for a valid public opinion survey?

The assessments for BE activities 1.1.3, 3.1.2, 3.1.7, 4.1.1, 4.1.4, 4.1.5, 4.1.8, 5.2.3 and 5.3.4 can be found in the BE curriculum and apply to benchmark 9.1.3.3.2. These assessments will be specific the to particular project or design activity, but include either a detailed written report and/or class presentation which communicates students' results, procedures, and design processes. Assessments for 2.1.2 and 2.1.3, described above, are also good examples for addressing benchmark 9.1.3.3.2.

Differentiation:

Gifted and Talented

A possible modification would be to assign students to create a presentation summarizing the history of biotechnology events and present it to the class as part of instruction. This can also help struggling students who need more guidance on the historical questions and the other students get to hear from their peers about these important events.

Gifted students could also extend themselves by communicating their design projects or experimental results for any activity in a new, creative format, such as creating a web page to "market" their design or video commercial.

Special Education

The activities are very research intensive, which can be difficult for struggling readers and those with limited biology knowledge. Look for key words or dates in passages can help students to find relevant material for further consideration. When the activity calls for students to work on their own, clearly delineating tasks to complete, breaking up the reading into smaller portions, and giving more time for processing can be helpful.

Special education students who have difficulties with writing may struggle with written reports. In this case, either providing time for peer-feedback and editing on each section or teaming students so that they are only responsible for a portion of a report might work.

English Language Learners

The vocabulary that each student encounters will be different and allowing students to share their gathered knowledge is very helpful to students with emerging English language skills. ELL students can share things they find and get answers to questions as they go. It may be helpful to use the list of vocabulary listed with the lesson in the BE curriculum and have the students jigsaw definitions in small groups as these words will quite frequently confuse ELL students.

Parents and Administration:

Administrative/Peer Classroom Observation

Students Are:	**Teachers Are:**
researching history and background	answering questions
giving oral presentations	guiding students to relevant resources
discussing opinions and values	holding students accountable to tasks assigned
updating stock portfolios	helping students to make connections to other disciplines
writing reports and peer editing	reviewing student work
identifying risks and benefits	

Professional Learning Communities

Professional Learning Communities may find it useful to discuss the following questions:

- In what ways do we ask our students to *defend* or *justify* their procedures and results from investigations or design projects?
- How can students communicate their results with one another?
- Which social, economic and ecological issues are relevant for our population of students?

The following resources may provide an additional opportunity for reflection and growth on these topics:

- *Why Teach Bioethics?*
  http://www.actionbioscience.org/education/csongradi.html
- *Literacy in the Science Classroom*
  http://www.prel.org/products/paced/oct04/ms_literacy.pdf

- *Teaching Science Literacy* http://www.ascd.org/publications/educational-leadership/mar11/vol68/num06/Teaching-Science-Literacy.aspx

Parent Resources:

Students are often anxious about oral presentations. Parental support is a huge part of success in any presentation. This may apply to poster paper purchase, encouragement and support in completion, and serving as a practice coach for presentation. Parents can and should offer their impressions of the presentation and support the efforts of their children.

Discussing ethics, values, beliefs, and opinions on controversial subjects with your child will help them to be able to justify their own position and learn to listen to the opinions of others without harsh judgment.

A discussion of perceived limitations on scientific research due to ethical values would be very appropriate here. How does your family or group feel about stem cell research, genetic engineering, or nuclear power?

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