PLTW BE Science Framework

PLTW Course: Biotechnical Engineering (BE)

Science Strand being addressed: Strand 1: Nature of Science and Engineering
Science Sub-strand being addressed: Sub-strand 2: The Practice of Engineering

Science Standard being addressed: 9.1.2.1

Overview:

MN Science Standard and Benchmarks: 9.1.2.1.1, 9.1.2.1.2, 9.1.2.1.3

Standard 9.1.2.1: Engineering is a way of addressing human needs by applying science concepts and mathematical techniques to develop new products, tools, processes and systems.

Benchmark 9.1.2.1.1: Understand that engineering designs and products are often continually checked and critiqued for alternatives, risks, costs and benefits, so that subsequent designs are refined and improved. *For example:* If the price of an essential raw material changes, the product design may need to be changed.

Benchmark 9.1.2.1.2: Recognize that risk analysis is used to determine the potential positive and negative consequences of using a new technology or design, including the evaluation of causes and effects of failures. *For example:* Risks and benefits associated with using lithium batteries.

Benchmark 9.1.2.1.3: Explain and give examples of how, in the design of a device, engineers consider how it is to be manufactured, operated, maintained, replaced and disposed of.

Correlation to AAAS Atlas (Benchmarks for Science Literacy):
3A/H4**, 3B/H1, 3B/H4, 3B/H6, 3C/H3*, 12EST1, 12EST1.1, 12EST1.2, 12EST1.3, 12EST1.4, 12EST1.5

- Engineers use knowledge of science and technology, together with strategies of design, to solve practical problems. Scientific knowledge provides a means of estimating what the behavior of things will be even before they are made. Moreover, science often suggests new kinds of behavior that had not even been imagined before, and so leads to new technologies. 3A/H4** (SFAA)
- In designing a device or process, thought should be given to how it will be manufactured, operated, maintained, replaced, and disposed of and who will sell, operate, and take care of it. The costs associated with these functions may introduce yet more constraints on the design. 3B/H1

- Risk analysis is used to minimize the likelihood of unwanted side effects of a new technology. The public perception of risk may depend, however, on psychological factors as well as scientific ones. 3B/H4
- To reduce the chance of system failure, performance testing is often conducted using small-scale models, computer simulations, analogous systems, or just the parts of the system thought to be least reliable. 3B/H6
- 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*

Correlation to NSES (National Science Education Standards):
Abilities of technological design (12EST1)
- Identify a problem or design an opportunity (12EST1.1)
- Propose designs and choose between alternative solutions (12EST1.2)
- Implement a proposed solution (12EST1.3)
- Evaluate the solution and its consequences (12EST1.4)
- Communicate the problem, process, and solution (12EST1.5)

Essential Understandings/Big Ideas:

Engineering is the application of science and math to solve problems and improve the human condition. During the design process, engineers continually evaluate, refine, and improve the design in order to meet required criteria and constraints. Risk analysis allows engineers to identify and weigh the benefits versus the risks for several alternative designs while keeping in mind the cost, manufacturing, operation, maintenance, and disposal of the finished product.

For example, in Project 4.1.3 Fueled by Fungi, students must design a race car that utilizes fermentation as its sole energy source. In addition, students weigh the trade-offs between modifications that will improve vehicle operation versus keeping costs and overall material use to a minimum. Refinements in their design are made as failures occur during testing. In addition, students must consider what maintenance has to occur between trial runs and how to refuel the vehicle.

What should students know and be able to do [at a mastery level] related to these benchmarks?
Students should be able to:
- Understand that during the design process, designs and products are continually evaluated in order to refine and improve them.
- Identify the risks and benefits of alternative designs.
- Evaluate how a change in the design may affect the overall cost, manufacture, operation, maintenance, or disposal of a design product.

Misconceptions:

Student Misconceptions

- There is one best “answer” or design solution that will have absolutely no risks or failures.
- Improving a design means that materials and features need to be added or the design must become more complicated.

Teacher Resources:

Teacher Notes

This standard will be addressed in several of the design projects and activities in the Biotechnical Engineering course. Three of the best opportunities for students to address risk analysis, materials constraints, and manufacturing include:

- **Activity 3.1.7 Designer Genes: Industrial Applications.** In this activity, students design a practical application for the green fluorescent gene or protein.
- **Activity 4.1.2 Optimizing Yeast Fermentation and Project 4.1.3 Fueled by Fungi.** Students use the design and modification process to build race cars powered by yeast fermentation.
- **Projects 5.2.2 Orthopedic Implants and 5.2.3 Material Properties of Joints.** The students research materials and manufacturing processes involved with implantable devices and replacement joints.

For all applications, it is important to give the students a list of materials they are allowed to use for building their devices and models as well as identify any criteria and constraints. If students can justify obtaining materials from outside the classroom, those materials should be allowed. However, there is great value in limiting the available resources as this will foster more innovation to solve the resource problem.

As students are introduced to equipment and materials and design their product, they should think about the cost, benefits and risks associated with the manufacture, use and disposal of the product. Often this can be tied to the operation and safety involved in using the device or product. Federal and industry regulations should also be considered. For Activity 3.1.7 in particular, students may have difficulty understanding the scaling-up process and that materials change in cost and quality in larger batches. Although it is difficult to fully illustrate this for the students, they will need some examples of how this might work.

For Activity 4.1.2 and Project 4.1.3, it is essential that students are given a clear objective and criteria that their vehicle designs must meet (for example, forward movement or a low fuel-to-distance ratio). As they optimize their fuel system and modify their vehicle designs, students should be encouraged to research and discuss the benefits and risks of each modification with their student teams before they actually make those changes to their design.

In Projects 5.2.2 and 5.2.3, students need to research the cost and effectiveness of materials used in implantable devices as it pertains the their particular assigned joint. Whether or not a medical procedure or device is used on a patient is often determined by weighing the cost verses benefit or the risk verses benefit of the procedure or device. Examples include everything from removing a mole, to performing an amniocentesis, to implanting a biomedical device. When the risk involved in the procedure is greater than the benefit, it is not an appropriate procedure.

Additional Instructional Resources
The following video provides an engineers perspective on the role of risk analysis. The entire talk can be viewed, or specific chapters. Access the video via the web at: http://ecorner.stanford.edu/authorMaterialInfo.html?mid=2364.

New Vocabulary

- *product* - The final outcome of the engineering process.
- *risk analysis* - A systematic assessment of the benefits and risks of the project. Unless the benefits outweigh the risks, the project should not be undertaken.

Vignettes:

Vignette #1:

In this conversation the students are being encouraged to accomplish a task without having everything they think they need. This forces the students to think of other methods of solving a problem that use the resources available.

Teacher: Tell me about your design.

Student: Well, this is our design, and here are some things we are going to need. But, there are a few thing I can't find in the supply closet.

Teacher: What are you going to do about that?

Student: Can you get these parts for us?

Teacher: I might be able to. Is there any way you can accomplish the same result with the materials available?

Student: We didn't think of that. We will talk about it and give you a new design.

Vignette #2:

In this scene the student is verbalizing the process of weighing pros and cons of a design decision.

Teacher: I see that you increased the length of the lever on your yeast mobile vehicle. What did you hope to gain form that modification?

Student: Well, even thought we had to use more material and it made the vehicle slightly heavier, we thought that a longer lever would pull a much greater length of string and cause the axle to turn many more revolutions so the car would go further.

Teacher: Ah, I see. So, there was a trade-off, but do you think the benefit of more revolutions outweighed the risk of a heavier vehicle?

Student: Yes. We tested it, and with the same fuel system, the car went further than it did with the shorter lever. But, now we need to figure out a way to easily refuel the car.

Teacher: O.K. Let me know what you come up with.

Assessments:

Assessment Methods

Assessments will be specific the to particular project or design activity, but should include either a detailed written report and/or class presentation which outlines students' design process, modifications, material costs, and risk/benefit analysis.

3.1.7 Assessment

- Students will create a written proposal for their industrial application including thumbnail sketches of proposed designs, sketches of the finished proposal and a prototype of the application. Students will reflect on the quality of their models and evaluate the models of other students using a provided rubric (see rubric 3.1.7 in BE curriculum).

4.1.3 Assessment

- Students will write a detailed engineering report includes a description of the entire design process including all modifications, rational for the modifications, the preliminary test results, and suggested improvements for the design. There should be pictures of the final product and sketches of the original design as well as an explanation of how the yeast mobile works and how it relates to the understanding of fermentation (see rubric 4.1.3 in BE curriculum) A presentation to the class should include justification for the design and preliminary results along with sketches and modifications.
- Relevant conclusion questions for 4.1.3:
    - What is the optimal biomass (fuel) or yeast combination to power a vehicle?

    - How does the efficiency of yeast power compare to a combustion engine?
    - What are the benefits of designing machines that utilize renewable energy?
    - What are the advantages to the use of the current biofuels over gasoline?

5.2.2 Assessment

- Student teams will design and create prototypes for orthopedic implants and devices. Each student will create journal entries which track his/her progress in the development of replacement joint prototypes and which document challenges throughout the design process.
- Student teams will create a design portfolio including:
    - Anatomical features and movements.
    - Sketches and drawings of an implant.
    - Pictures and sketches of a constructed joint model.
    - WebQuest on material and manufacturing process research.
    - Cost list of implant materials and manufacturing processes.
    - Estimated surgical cost.
    - Proposed surgical procedure.
- Relevant conclusion questions 5.2.2:
    - What are the FDA regulations that pertain to your design?
    - What are the materials you are considering for your design? Why are you considering these materials?
    - In what way would a patient benefit from the implant? Are there others who would also benefit?
    - What are the most common materials used for joint implants or replacements? What everyday products contain these common materials?
    - What are the recommended surgical procedures and projected costs of surgery?

Differentiation:

Gifted and Talented

Asking students to make a list of “what would you try next” and even allowing those students to make a new modification to their design.

Special Education

Allow students to dictate their ideas to a recorded for those who have trouble writing. Intentionally assign groups that will pair students that have difficulty with reading with other students that will read and do research.

English Language Learners

Much of the engineering vocabulary can be problematic even for students who speak fluent English. It is important that all students get in a habit of looking up unfamiliar words and ask for help. If all students are required to do this, it fosters a culture of learning and collaboration that encourages students to work together and understand complicated concepts.

Deliberately grouping students who speak the same language at different levels can help students that are less comfortable with new vocabulary.

Parents and Administration:

Administrative/Peer Classroom Observation

Students Are:	**Teachers Are:**
sketching designs	providing constructive feedback
building models or products	obtaining needed materials
discussing ideas and concepts, including the risks and benefits	providing conceptual support with examples
testing and recording results	
refining their design or prototype	
tracking their budget and materials used	

Professional Learning Communities:

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

- How can we use decision matrices in helping our students to evaluate their designs?
- In what ways can we insert peer-evaluation and self-critique strategies into our lessons?

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

Systematical Approach to Ethical Decision Making Using Matrices: http://fie-conference.org/fie2008/papers/1097.pdf.

Parent Resources:

Parents can discuss how they choose which products to purchase and discuss the benefits and risks of each product with their child.

Additional discussion could include how they recycle products when they wear out. What do they do with batteries? How are electronics disposed? Old paint? Tin cans? If they don't have their own recycling program at home, this would be an opportune time to start one with their child.

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