Skittles and Drug Design!!

Adapted from the Bench to Bedside 2016—Designing Protective Drug Coatings Activity

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## Abstract

Teaching engineering practices can be intimidating for many teachers. The Bench to Beside: Biomedical Explorations teacher professional development program introduced a great inquiry based engineering lab activity that could be adapted for classroom use at any grade level. *Designing Protective Drug Coatings* biomedical engineering lab introduces students to the career field of biomedical engineering and helps students connect the use of biomedical prototypes to the patient. This lab was adapted to introduce my students to the engineering design cycle and how it compares to the scientific method. Student have the opportunity to develop their own prototype using skittles as the model drug that needs a coating to last a specified amount of time. Students also hone disciplinary literacies by producing a written summary of how they designed their prototype.

## Rationale

Physical science is a course taken by 9th graders in my school district. This is a challenging course which requires stellar comprehension and mathematical skills; however, many of the students in this course are considered to be low performing students in reading and in mathematics. The common struggle among these students is deciphering what is being asked in a problem and performing the mathematical computation required. In my experience of teaching this course, well over 65% of my students are considered to be in the range of level one to level two according to the Florida Standards Assessment (FSA). These low FSA scores imply students struggle to understand complex text and struggle to use analytical reasoning skills to solve problems. Although many of the students enrolled in this course struggle in comprehension and analytical reasoning, the study of physical science offers these students the unique opportunity to improve upon reading comprehension and analytical reasoning skills through hands on investigations. Depending on the type of lab investigation, the content may allow the student to hone both comprehension and analytical reasoning skills.

Part of the physical science standards require the implementation of Science and Engineering Practices as listed below from CPALMS Physical Science Course Standards (2015):

- Asking questions (for science) and defining problems (for engineering).
- Developing and using models.
- Planning and carrying out investigations.
- Analyzing and interpreting data.
- Using mathematics, information and computer technology, and computational thinking.
- Constructing explanations (for science) and designing solutions (for engineering).
- Engaging in argument from evidence.
- Obtaining, evaluating, and communicating information (CPALMS, 2015).

The percentage of teachers which feel adequately trained to implement the engineering practices is approximately 7% (Boesdorfer & Greenhalgh, 2014). I commonly incorporate science practices into my lab investigations and into my instruction; however, I have yet to successfully implement engineering practices.

Wilson, et. al. (2014) provide evidence that disciplinary literacies of the engineering practices can help students to improve comprehension and analytical reasoning skills through practicing written communication based upon lab investigations. My school improvement goal is to improve student writing scores on FSA Writing assessment. By giving my students content area writing activities, this goal can be achieved. The *Designing Protective Drug Coatings* from Bench to Beside, will be a great way to introduce my 9th graders to content area writing.

## Action Research Intervention

Finding activities that make the engineering design cycle relevant to my students will help them to be engaged with working towards improving their analytical and comprehension skills. The *Designing Protective Drug Coatings* biomedical engineering activity would help me to create an engaging activity to teaching the engineering practices and incorporate disciplinary literacies as part of the design cycle.

Students will learn about biomedical engineering by modeling engineering practices with simulated a drug design activity. They will be required to produce a short written report about their design process and outcome.

## Changes to Action Research Intervention

My action proposal from the institute had to be rewritten due to transferring schools and losing the opportunity to teaching biotechnology with an emphasis in biomedical science. I had planned on using Team-Based Learning to measure the outcome of teaching the biomedical science concepts from Bench to Beside to my biotechnology students, but was not able to complete this as a result of transferring schools.

I was able to incorporate the biomedical engineering activity into my physical classes and my student enjoyed the activity and are excited about learning more about biomedical sciences.

## Connections to Bench to Bedside Summer Institute

The *Designing Protective Drug Coatings* activity, created by the Hudalla Lab Group, introduces students to the career field of Biomedical Engineering and applications of how drug design goes from prototype drug to the patient. This lab activity is targeted for elementary and middle school students; however, there are multiple ways this lab activity can be extended to be used at the high school level.

## Data Collection and Analysis

Students will be given a pre-test to compare what they know about the difference between the scientific method and the engineering design cycle. The same test will be given to the students at the end of the activity to see if they have retained the steps and content vocabulary of the design cycle. Students will be asked if they can describe what an engineer is during a class discussion. This will be a formative assessment to guide instruction. Following the engineering design activity students will write a one to two paragraph analysis of their design based upon the design cycle and reflect upon how they could have made their design better to fit within the parameters of the design criteria.

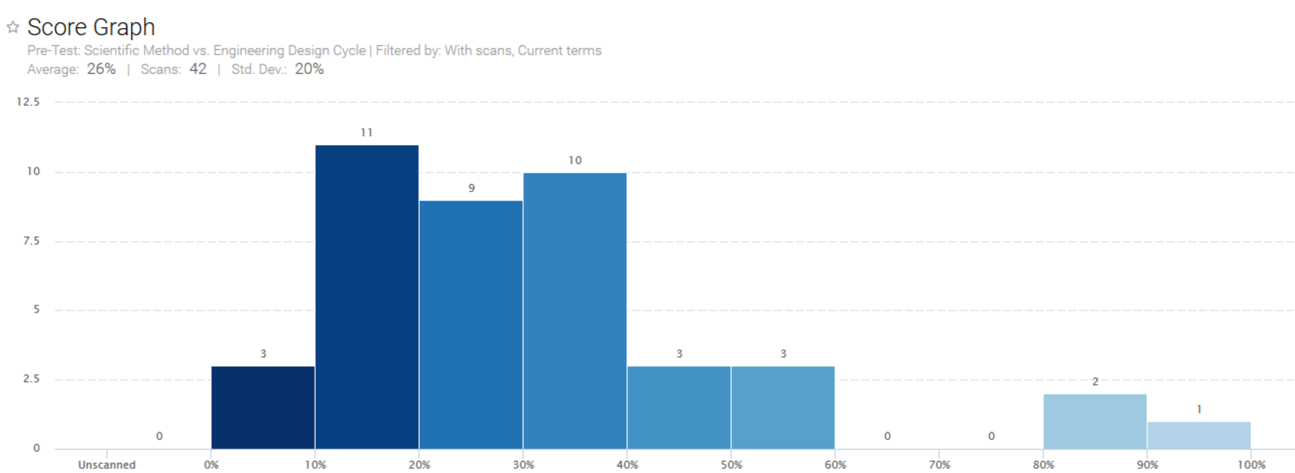


Figure 1. Graph displaying the spread of pre-test grades. Most of my student were not familiar with the engineering design cycle.

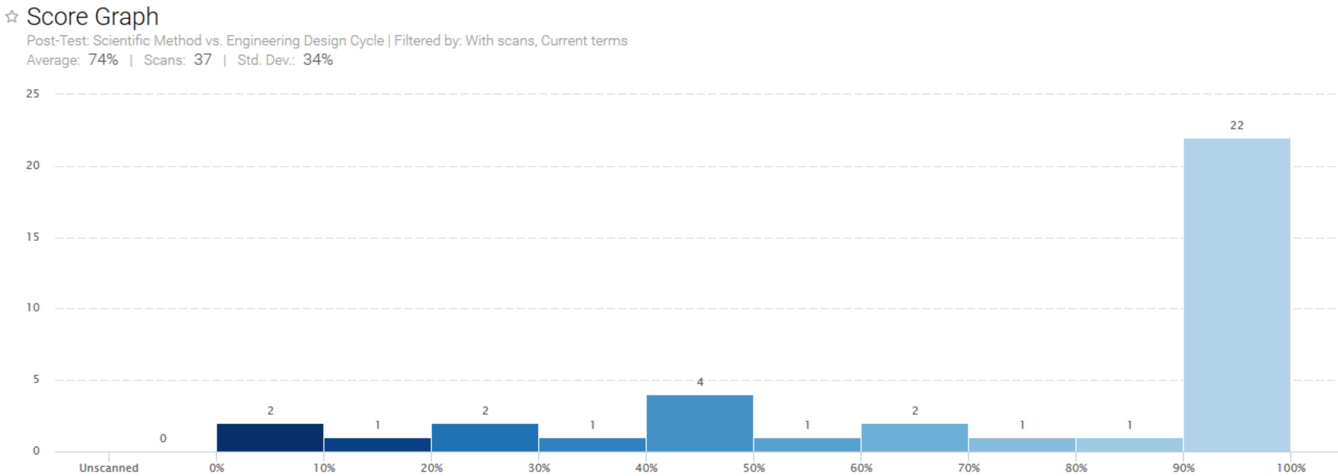


Figure 2. Graph displaying the spread of post-test grades. Most students did retain the steps of the design cycle.

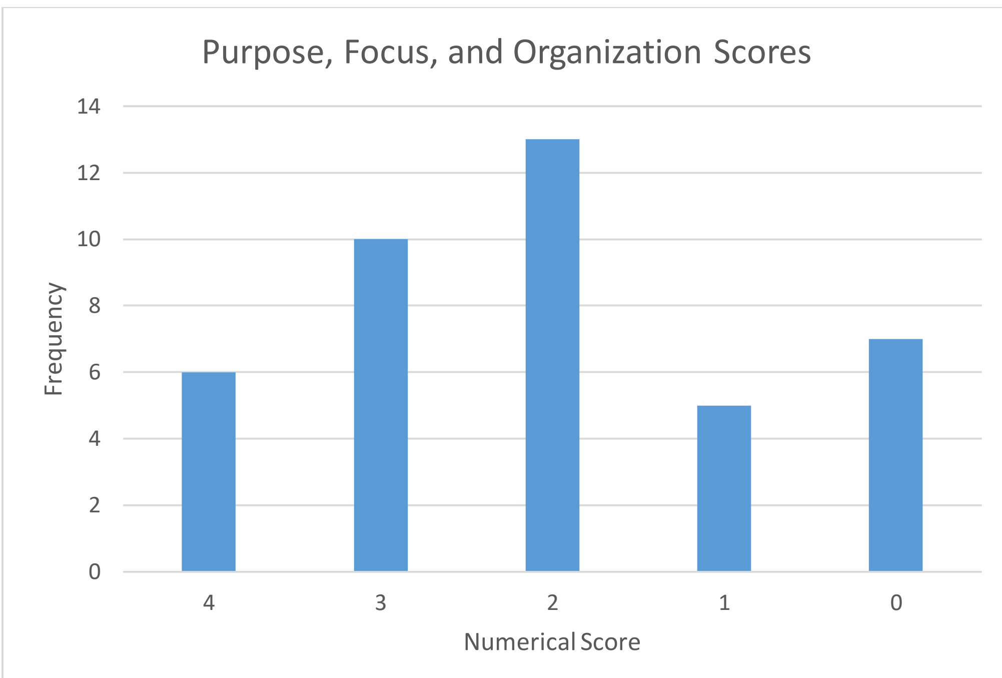


Figure 3. Graphical analysis of activity writing analysis scores. Most students scored a two which implies the need for further development of content area writing skills.

Based upon the data presented in figures 1, 2 and 3, this activity was successful in teaching my students about biomedical engineering and the design cycle. Class discussion occurred about the relationship of biomedical engineering to patient care. As figure 2 displays that many of my students can understand the steps of the design cycle; however, when describing the process as it relates to the creation of a prototype, they struggle. Figure 3 shows that most of my students only partially express the use of the design cycle through written communication.

For both scientist and engineers, technical writing is a required skill. Proficient writing is also required for those which assist professional engineers and scientist. Based upon this data, my students must continue to work on content area writing in order to be successful in their careers. I will continue to require my students to write using lab activity specific vocabulary in writing summaries of the investigation. This will hopefully improve their writing skills and lay the foundation for the students to successful in biomedical training, should they chose that career path.

## Literature Cited


Boesdorfer, S., & Greenhalgh, S. (2014). Make Room for Engineering. Science Teacher, 81(9), 51-55.

CPALMS. (2015). Physical Science Course Standards. Retrieved from http://www.cpalms.org/Public/PreviewCourse/Preview/13114

Wilson, A. A., Smith, E., & Householder, D. L. (2014). Using Disciplinary Literacies to Enhance Adolescents' Engineering Design Activity. Journal of Adolescent & Adult Literacy, 57(8), 676-686.


## Budget Justification

The cost associated with this lab is minimal. Sugar, corn starch, flour, cooking oil diet sprite, and skittles can be purchased for around $30.00 for 6 periods of students, if the skittles are purchased in a large bag. The glassware used is readily available in my classroom. There is no need for plastic cups or containers for this lab.

## Permissions

At this time there are not any additional permission I need to obtain. This activity fits in the with the sequence of the instructional pacing guide of my school district.

**LESSON PLAN**
**By Denise R. Newsome M.Ed.**
**Based on the Bench to Beside 2016 Designing Protective Drug Coatings Activity**

**TITLE:** Skittles and Drug Design!!

**KEY QUESTION(S):**
- How can the Engineering Design Process be applied to drug coatings?
- What are the properties biomedical engineers must consider when designing drug coatings?

**SCIENCE SUBJECT**: Physical Science

**GRADE AND ABILITY LEVEL**: 8th and 9th grade physical science

**SCIENCE CONCEPTS**: The concepts covered in this inquiry lab will be related to the nature of science standards and ELA benchmarks and standards.

**OVERALL TIME ESTIMATE:** Three 45 minute class periods.

**LEARNING STYLES**: Auditory, Visual, and kinesthetic.

**VOCABULARY:** (From the Hudalla Lab *Designing Protective Drug Coatings Activity*)
**anatomy** — The branch of science concerned with the bodily structure of humans, animals, and other living things.
**biomaterial** — Any material that interacts with the body to repair, augment, or replace the bodies' functions.
**biomedical engineer** — An occupation that use the principles of math, physics, and chemistry to design instruments and devices to solve clinical problems.
**degradable**—able to be broken down when reacted with another substance or will breakdown by natural means overtime.
**diffusion** — (verb: diffuse) The movement of molecules in a random fashion to create an evenly concentrated environment.
**drug** — Therapeutic agent; any substance, other than food, used in the prevention, diagnosis, alleviation, treatment, or cure of disease.
**drug delivery** — Engineering systems to help with the delivery of a pharmaceutical agent to a person or animal, to achieve a therapeutic effect. Drug delivery systems help get drugs where they're needed, at the levels needed to have the desired effect.
**efficacy** — The capacity for producing a desired result. For example, how much a drug is able to inhibit; if it causes 100% inhibition, it has a high efficacy.
**encapsulation** — (verb: encapsulate) As refers to pharmaceuticals, a shell-like method of coating drug molecules to enable release at specific times using diffusion.
**engineer** — A person who applies understanding of science and math to creating things for the benefit of humanity and our world.
**Engineering Design Process** — A series of steps that engineers follow to come up with a solution to a problem.
**oral administration** — A method of drug administration using the mouth and digestive tract to achieve adsorption into the bloodstream.

**physiology** — The branch of science that deals with the normal functions of living organisms and their parts.
**polymer** — A chemical compound that is composed of repeating subunits. They can be derived from nature or created in a chemical synthesis lab, and are commonly used in biomaterials engineering.
**prototype** — A first attempt or early model of a new product, device or creation.
**solubility** — The property of a substance to dissolve into solution.
**toxicity** — (adjective: toxic) The degree of harmfulness of a substance to humans.

**LESSON SUMMARY:**
Students will study the Engineering Design Process as it is applied by biomedical science engineering through an inquiry based lab in which students model the design process with a given set of materials to create a prototype drug coating. Students will practice disciplinary literacies by writing a summary of process they used in creating their prototype drug coating.

**STUDENT LEARNING OBJECTIVES WITH STANDARDS:**
The student will...

1. Be able to complete the Engineering Design Cycle by modeling the process of creating a coating around a skittle.
    a. Science and Engineering Practices (NCR Framework for K-12 Science Education, 2010): There are quoted from CPALMS Physical Science Course Standards (#2003310)
        i. Asking questions (for science) and defining problems (for engineering)
        ii. Developing and using models
        iii. Planning and carrying out investigations
        iv. Analyzing and interpreting data
        v. Using mathematics, information and computer technology, and computational thinking.
        vi. Constructing explanations (for science) and designing solutions (for engineering)
        vii. Engaging in argument from evidence
        viii. Obtaining, evaluating, and communicating information
    b. SC.912.N.3.5: Describe the function of models in science, and identify the wide range of models used in science.
2. Be able to define a problem and conduct and investigation
    a. SC.912.N.1.1: Define a problem based on a specific body of knowledge
3. Be able to use disciplinary literacies to write a summary of the creation of a prototype
    a. LAFS.910.RST.3.8: Assess the extent to which the reasoning and evidence in a text support the author's claim or a recommendation for solving a scientific or technical problem.

**MATERIALS:**
ESSENTIAL:
For this module, students will be provided with:

- Flour
- Sugar
- Corn Starch
- Vegetable Oil

- Diet Sprite
- Skittles (red or purple work best)

You will need the following materials if you do not have a general lab equipment for use:
- Paper plates
- Clear plastic cups
- Plastic spoons
- Mini-cups with sealable lids (for water and vegetable oil)
- Small Ziploc bags (to pre-measure solids)

SUPPLEMENTAL:
Ideally we want to reduce the amount of waste produce. Beakers could be used for this activity in lieu of plastic products.

**BACKGROUND INFORMATION**:
The following background information is written by the Hudalla Lab as part of their Biomedical Engineering Outreach Program.

"A **drug** is a specially made medicine that is used to improve your health if you are ever to become sick. Usually your doctor will prescribe you a particular type of drug, depending on the illness or disease that you may have. These drugs can be administered or delivered in many different ways, for example by mouth or injection. **Oral administration**, or delivery of a drug by the mouth, has its challenges. Sometimes the drugs we want to deliver orally can **diffuse** away too quickly; that is, the drug may break down into smaller sizes and disperse throughout the body too quickly. This is often a bad thing if you want your drug to stay in the stomach for a period of 10 days which is the typical duration of a stomach ulcer or bacterial infection. If that is the case, the drug has high **solubility** and therefore low **efficacy** because it is no longer around to do the job it was designed for. **Drug delivery** can be difficult for this very reason, therefore **biomedical engineers** who like most other **engineers** are challenged with developing a solution for a difficult problem. A biomedical engineer who works in the field of drug delivery typically uses various designs of a **biomaterial,** such as a **polymer,** before selecting one that can **encapsulate** or coat an oral drug. There are many criteria for this design process. For example, in order for his/her biomaterial to be safe to swallow, it must not be **toxic** or too large that it will block any pathways throughout the **digestive system.** An incredibly helpful tool that all engineers use, including biomedical engineers, is the **Engineering Design Process (Draw out Figure 1 to explain the process)**. Furthermore, it is important to a biomedical engineer that they understand human **anatomy** and **physiology**, especially if they plan on delivering their **prototype** drug coating into the sensitive parts of the body such as the stomach or intestines."

Part of this lesson is teaching the students the difference between the engineering design cycle and the scientific method. Class discussion should include the primary difference between the design cycle and the scientific method is the creation of prototype and how it is created to solve a problem or technological need.

The table below is an excellent description of the differences as created by the University of Cincinnati (2016):

| The Scientific Method | The Engineering Design Cycle |
|---|---|
| State a question or problem | Define a problem or need |
| Gather background information | Gather background information |
| Formulate hypothesis; identify variables | Establish design statement or criteria |
| Design experiment, establish procedure(s) | Prepare preliminary designs |
| Test hypothesis by doing an experiment | Build and test a prototype(s) |
| Analyze results & draw conclusions | Verify, test & redesign as necessary |
| Present results | Present results |

This table is used as a guide for helping students writing a summary of the design process. Although, we are using a step wide process for both methods, discussion should occur that science is not always completed in sequential steps.

**ADVANCE PREPARATION**:
Create stations for students to pick up a specified amount of each substance used in the lab.

**PROCEDURE AND DISCUSSION QUESTIONS WITH TIME ESTIMATES:**
Day One (45 Minutes): Pre-Test and Whole group instruction

- Whole group discussion (5 minutes): This will be used as a formative assessment to assess prior background knowledge by asking the class to respond to
    - What does an engineer do?
    - What is biomedical engineering?
    - What is the difference between the scientific method and the engineering design cycle?
- Pre-Test (10 minutes): Multiple choice assignment
- Lecture (30 minutes): Use PowerPoint

Day Two (45 minutes): Review of Design cycle and Lab Activity

- Review of Design Cycle and procedure for lab investigation (5 minutes)
- Students do the design lab (30 minutes)
- Evaluate students design using design rubric (10 minutes)

Date Three (45 minutes): Post-Test & Writing Assignment

- Post-Test (10 minutes)
- Review rubric for lab writing (5 minutes)
- Writing (30 minutes)

**ASSESSMENT SUGGESTIONS**:
<u>Objective 1 Assessment:</u> re-administer the pre-test to measure if the students can now match the correct order of the Scientific Method verses the Engineering Design Cycle.
<u>Objective 2 Assessment:</u> Teacher observations of lab performance and ability of students to work with peers to develop a viable model.
<u>Objective 3 Assessment:</u> students will write one to two paragraphs explaining what they did to complete the design cycle and explain their thoughts behind their drug coating prototype.

**Rubric for evaluating student design**

| Design Criteria | Group #1 | Group #2 | Group #3 | Group #4 | Group #5 | Group #6 |
|---|---|---|---|---|---|---|
| **Is the release of the drug reasonable? Color change occurs between 30 seconds – 4 minutes (5)** | | | | | | |
| **Would the coating be comfortable to swallow? (5)** | | | | | | |
| **Is the coating digestible and safe to swallow? (5)** | | | | | | |
| **Minimum number of materials used (5)** | | | | | | |
| **Total (20)** | | | | | | |

**Rubric Adapted from the ELA Grades 6-11: Informative/Explanatory Text-based Writing Rubric**

| Score | Purpose, Focus, and Organization |
|---|---|
| 4 | Clearly stated/strongly maintained controlling idea with little or no loosely related material. Used all required content vocabulary correctly and clearly explained the process of the design cycle. |
| 3 | Clear and maintained controlling idea, some loosely related material. Used most content vocabulary correctly and mostly explained some details of the design cycle. |
| 2 | Focused on the controlling idea, but insufficiently sustained or unclear. Used little content vocabulary correctly and partial explained some details of the design cycle. |
| 1 | Confusing or ambiguous ideas, little use of content vocabulary and little explanation of the design cycle. |
| 0 | Off topic ideas, no use of content vocabulary and no explanation of the design cycle. |

| Score | Conventions of Standard English |
|---|---|
| 3 | No errors in usage punctuation, spelling and sentence structure. |
| 2 | Some errors in usage punctuation, spelling and sentence structure. |
| 1 | Many errors in usage punctuation, spelling, and sentence structure. |

| | | | | | | |
|---|---|---|---|---|---|---|
| 7/7 100 A | 6/7 86 B | 5/7 71 C | 4/7 57 F | 3/7 43 F | 2/7 29 F | 1/7 14 F |

**EXTENSIONS:**
This lab could be extended for high school chemistry with a discussion of the properties of the substances used in this lab. The article, “Chemistry Meets Medicine,” could be used to provide evidence for a writing assignment. The article is found here (https://publications.nigms.nih.gov/chemhealth/med.htm)

**RESOURCES/REFERENCES:**

Hudalla, G. (2016). Designing Protective Drug Coatings Activity. [PDF]. Retrieved from Bench to Beside Canvas site.

University of Cincinnati. (2016). Scientific Method vs. Engineering Design Cycle. Retrieved http://research.uc.edu/sciencefair/resources-forms/topic-suggestions/scientific-method-v-engineering-design-procedures.aspx (The tables on the pre and post assessment came from this website. This website is no longer available.)

Pre-Test and Post-Test Handout

# Scientific Method vs. Engineering Design Cycle

**READ THE FOLLOWING DIRECTIONS:** There are two tables below titled: **The Scientific Method** and **The Engineering Design Cycle**. Select the answer on the bubble sheet to match the correct order of the process of the Scientific Method and the Engineering Design Cycle.

Options to select to fill the tables below.

| | |
|---|---|
| a. Prepare preliminary designs | b. Define a problem or need |
| c. Test hypothesis by doing an experiment | d. Formulate hypothesis; identify variables |
| e. State a question or problem | f. Analyze results & draw conclusions |
| g. Establish design statement or criteria | h. Design experiment, establish procedures |
| i. Verify, test & redesign as necessary | j. Build and test prototypes(s) |

| The Scientific Method |
|---|
| 1. |
| Gather background information |
| 3. |
| 5. |
| 7. |
| 9. |
| Present results |

| The Engineering Design Cycle |
|---|
| 2. |
| Gather background information |
| 4. |
| 6. |
| 8. |
| 10. |
| Present results |