SAVING A LIFE: HEART VALVE REPLACEMENT

Teacher Background:

- Small groups of 3-4
- Duration: two 45–50-minute classes
- Setting: indoors

Pre-stem activities: (*check pre/post STEM heart valve pdf*)

- Review important vocabulary/definitions pertaining to heart valves.
- Participate in group brainstorming.
- Students will go through the engineering design process stages of brainstorming, designing, building, testing and redesign and answer a series of questions as a group prior to starting their heart valve model.
- Optional: **Engineering the Heart: Heart Valves associated lesson.**

Rationale/Objectives:

- After this activity, students should be able to:
  - Describe how real, healthy heart valve's function.
  - List some diseases that can affect the heart valves.
  - Explain pros and cons of different types of artificial heart valves.

Method:

Because diseases of the heart and circulatory system are a leading cause of death in the U.S., artificial heart valves are a leading area of research for biomedical engineers. Heart valve diseases can be fatal if the valve is not replaced. Engineers and physicians use the engineering design process to collaborate to design valves made of materials that the human body accepts and function for as long as possible, and that require the least invasive implantation procedures. This process involves asking to identify the needs and constraints, researching, imagining possible solutions, planning by selecting a promising solution, creating a prototype, testing, and improving the designs so they are dependable solutions to replace non-functioning heart valves.

Materials:

Each group needs:

- 1 sheet of paper and a pencil or pen
- 1 pair of scissors
- 1 model heart, a cardboard box with a divider in the middle
- 30 marbles (representing blood cells)
- Valve Replacement Project Worksheet, one per group

To share with the entire class:

- tissue paper, 1 pack
- construction paper, 1 pack

- cardboard, scrap pieces, about 1 per group
- brown paper bags, available at grocery stores
- Popsicle sticks, available at hardware and hobby stores
- index cards, 1 pack
- wooden toothpicks, one box
- string, 1 roll (~280 ft or ~85 m)
- aluminum foil, 1 box
- duct tape, 3 rolls
- scotch tape, 5-10 rolls

The Activity (Directions):

1. Review the seven basic steps of the **engineering design process**: 1) ask to identify the need or problem, 2) research the problem, 3) imagine different designs, 3) plan by selecting the best idea 5) create a prototype, 6) test and analyze, and 7) improve and re-design.
2. Show students the large-scale model heart boxes and explain the design challenge, testing and evaluation.
3. Explain to students that their challenge is to design, construct and implant replacement mitral valves that allow the marbles to flow from the left atrium to the left ventricle, but not back the other direction when the heart box is tipped. The test for each heart valve is simply to tip the heart box towards the left ventricle and count how many marbles pass through into the left ventricle and then tip the heart box back towards the left atrium and count how many marbles *remain* in the left ventricle.
4. Show students how the **worksheet** outlines the test evaluation procedure and scoring point system for grading their designs. Overall, scoring is based on how well a valve allows marbles to enter the left ventricle and does not allow marbles to move back into the left atrium, the materials used (stronger "engineered" materials lose more points), and bonus points for bicuspid valves (having two leaflets or flaps that open and close). As necessary, go through an example on the worksheet.
5. Direct groups to brainstorm ideas for their replacement valve designs and draw sketches of their ideas, labeling the materials they plan to use. When choosing materials, make sure they consider the "cost" of materials, based on the point system provided on the worksheet.
6. Have each group choose two or three mitral valve designs to test. Let them know that they can alter their designs based on the test performance of their first valve design.
7. After checking their valve designs, give each group a pair of scissors, a model heart box, and 30 marbles. Students do not have specific constraints on materials, other than keeping in mind that some materials cause them to lose more points than others. Have them return any unneeded materials.
8. Once groups have finished building their replacement valves, direct them to "implant" the prototype valves in their model heart boxes between the two chambers. Then have them test their valves by putting all the marbles on the left atrium side and tipping the box so that (hopefully) all the marbles travel through the valve into the left ventricle. If

marbles do not make it through, count and record on the worksheet how many made it through and how many did not. Then tip the box back the other way and (hopefully) the valve blocks any marbles from traveling back into the left atrium. Again, count and record how many.

9. After scoring its valve design, have each group work on its next design iteration and repeat steps 5-7.
10. After testing, have teams complete their worksheets to score their designs. Points are based on effectiveness (how well the valve functioned during testing), choice of materials used, and how similar the valve design is to a real bicuspid mitral valve.
11. When 10 minutes remain in the class period, have students clean up.
12. After clean-up, have groups write their best scores on the board. Give each group 30 seconds to 1 minute to describe to the class their best design and explain why.
13. Assign students to write one-page reflection and evaluation reports.

<u>Possible extensions & variations:</u>

- Engineering the Heart: Heart Valves associated lesson.

<u>Skills for Success:</u>

- Collaboration, Communication, Problem Solving

<u>Related career</u>: Nursing

<u>Reflection:</u>

Ask students to respond to the following questions:

- What materials did you choose? Why?
- How does your valve allow marbles through in one direction and stop them in the other direction?
- What decisions did you make that might be similar to those made by biomedical engineers?
- What is the best aspect of this design?
- What improvements would you make to this design?
- How did you incorporate what you learned from testing into your next design iteration?