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| **Lesson Title :** Minimally Invasive Surgical Devices | **Unit #:**  **1** | **Lesson #:**  **2** | **Activity #:**  **1** |
| **Activity Title:** Designing a Surgical Device |

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| **Estimated Lesson Duration:** | 13 days |
| **Estimated Activity Duration:** | 12 days |

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| **Setting:** | Classroom |

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| **Activity Objectives:** |

* Students will discover how an action performed outside the body can translate into an action performed inside the body
* Students will use the engineering design process to design a device that can be used in a minimally invasive surgery to clamp and cut an artificial animal organ
* Students will use the engineering design process to create a prototype for a device that can be used in a minimally invasive surgery to clamp and cut an artificial animal organ

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| **Activity Guiding Questions:** |

* How can you translate an action performed outside the body into clamping down on something inside the body?
* How can you translate an action performed outside the body into cutting something inside the body?
* What are the size limitations of minimally invasive surgery?
* How can you see inside the body during minimally invasive surgery?

| **Next Generation Science Standards (NGSS)** | |
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| **Science and Engineering Practices (Check all that apply)** | **Crosscutting Concepts (Check all that apply)** |
| Asking questions (for science) and defining problems (for engineering) | Patterns |
| Developing and using models | Cause and effect |
| Planning and carrying out investigations | Scale, proportion, and quantity |
| Analyzing and interpreting data | Systems and system models |
| Using mathematics and computational thinking | Energy and matter: Flows, cycles, and conservation |
| Constructing explanations (for science) and designing solutions (for engineering) | Structure and function. |
| Engaging in argument from evidence | Stability and change. |
| Obtaining, evaluating, and communicating information |  |

| **Ohio’s New Learning Standards for Science (ONLS)** |
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| **Expectations for Learning - Cognitive Demands (Check all that apply)** |
| Designing Technological/Engineering Solutions Using Science concepts **(T)** |
| Demonstrating Science Knowledge **(D)** |
| Interpreting and Communicating Science Concepts **(C)** |
| Recalling Accurate Science **(R)** |

| **Common Core State Standards -- Mathematics (CCSS)** | |
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| **Standards for Mathematical Practice (Check all that apply)** | |
| Make sense of problems and persevere in solving them | Useappropriate tools strategically |
| Reason abstractly and quantitatively | Attendto precision |
| Construct viable arguments and critique the reasoning of others | Look for and make use of structure |
| Model with mathematics | Look for and express regularity in repeated reasoning |

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| **Unit Academic Standards (NGSS, ONLS and/or CCSS):** |

* Design, evaluate, and refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.
* Design criteria and constraints, which typically reflect the needs of the end-user of a technology or process, address such things as the product’s or system’s function (what job it will perform and how), its durability, and limits on its size and cost.
* Both physical models and computer models can be used in various ways to aid in the engineering design process.  Physical models, or prototypes, are helpful in testing product ideas or the properties of different materials.
* When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts.

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| **Materials**: |

Computers or Laptops (for day 1)

For Testing:

* Long balloons (at least 10 per group)
* Small water balloons (6-10 depending on size of bowl or bucket)
* Phantom crystals (<http://www.arborsci.com/phantom-crystals>)
* Food coloring
* Large bowl or bucket
* Water
* Scale
* Opaque covering for opening of bowl or bucket (such as sheet of plastic tablecloth or rubber)
* Wall & pipe inspection camera
* 1 piece of 1” PVC pipe – cut to 8” length (one per group + one extra)

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| **Teacher Advance Preparation:** |

Fill several long balloons with water for students to use on days 2-5

**Prior to Testing:**

* Tie long balloons in half, fill with phantom crystals (about 20-30 crystals) and 3-5 drops of food coloring, then fill with water
* Fill small balloons with water
* Fill bowl/bucket with water
* Place balloons in bowl/bucket
* Cover top of bowl/bucket with opaque covering and place two slits in covering – one for students’ device and one for the camera (one slit should be in the center of the covering, the other a few inches away) – final testing only

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| **Activity Procedures:** |

**Day 1: Introduction to Challenge & Research**

Start by telling students about the challenge, as follows:

Design and create a prototype of a device that can be used in a minimally invasive surgery to clamp and cut an artificial animal organ (made of a long balloon filled with gelatin)

This device must meet the following criteria and constraints:

* Must be able to be used by one person to clamp and cut
* Must fit through an 8” long, 1” PVC pipe
* Must be made of material that is able to be submerged in water
* Must cut within two inches of the center of the balloon

To motivate students and to help them understand what is involved in minimally invasive surgery, show the following video:

<https://www.youtube.com/watch?v=DmgYBL0pvKI&safe=active>

Once students understand the challenge, they should spend the remainder of the class time researching minimally invasive surgery instruments. One useful website for students to start with is:

<https://www.distance.purdue.edu/training/cssp/lessons/pdf/lesson120.pdf>

**Days 2 – 5: Prototype Design & Building**

During these days, student groups will work to design and build their device. They will provide their own supplies according to their design and research on what materials will meet the requirements and constraints. To allow them to test their ideas, balloons filled with water should be available to them as well as one of the PVC pipes so they can ensure their device will fit through the pipe.

**Day 6: Preliminary Testing**

On this day, student groups will have the ability to test their prototype for the first time on the crystal-filled balloon in water. No mass data will be taken here, rather students will judge their success on visual inspection of whether crystals leaked out of the balloon or not. Also, no covering on the bucket/bowl will be used during this testing so as to simplify the process. To test, the PVC pipe will be held so that a portion of the pipe will be submerged in the water. Students will place their device through the pipe and attempt to clamp and cut the balloon.

**Days 7 – 9: Redesign & Continued Testing**

Based on the results from the preliminary testing, students will continue to change their design to meet the requirements. Students should have access to the testing apparatus during this time so they can test each redesign.

**Days 10 & 11: Learning to use the Camera**

The opaque covering and camera should be added to the testing apparatus on day 10. Slits will be placed in the covering for the PVC pipes – one for their apparatus and one for the camera. Students should be introduced to how the camera works and allowed to use the testing apparatus to become comfortable with using their device in this limited-sight situation. Students should have access to the complete testing apparatus for the remainder of day 10 as well as day 11.

**Day 12: Final Testing**

Each student group will test their devices one at a time. To do this, each group will insert their device into PVC pipe in the slit created in the center of the opaque covering and the camera into the PVC pipe in the other slit. Using the video on the camera screen, the students will locate and attempt to clamp down and cut the artificial organ. Once students have completed their task, the camera should be removed (while the device is still clamping the artificial organ). Then, the covering along with the device and organ should be removed from the testing apparatus. A visual inspection for leaked crystals should then be performed, and any leaked crystals should be removed from the testing site and the mass of these crystals should be recorded.

**Formative Assessments:**

Students are required to write a daily entry in their engineering project notebooks. Each entry must include a description of what was accomplished with the project on that particular class day. Entries may also include an explanation of what is still to be accomplished and expected completion dates for various parts of the project, a summary of data taken, explanation for any choices made that day, or a summary of research performed either during class or outside class time.

In addition to the project notebooks, students will regularly test their devices throughout the design process. During this testing they will receive feedback on their device’s function, helping them to determine if they need to redesign a component of their device or if they can continue on to a new component.

**Summative Assessments:**

Project Rubric

Students are required to write a proposal explaining the following:

* Why there is a need for minimally invasive surgery in animals
* How their device can be used to improve upon a conventional surgery performed in animals
* The design features of their device

Students will follow the requirements for a proposal given in their textbook (Engineering Your Future, 2nd Ed., Great Lakes Press, pg 166-7).

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| **Differentiation:** |

No modification needed due to the small, homogeneous nature of the group of students (which includes no students with individualized education plans).

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| **Reflection:** |

Students really struggled with this challenge. Two of the three groups were able to successfully clamp the balloon within a reasonable amount of time (5-10 minutes), however upon attempting to cut the balloon one side of the clamp was unable to hold the balloon, thus allowing several crystals to leak out. Also all groups chose to forgo using the inspection camera in favor of a point deduction and using saran wrap to cover the testing site. Overall, I believe students were not given enough time to design a successful device. I originally planned to fill the balloons with gelatin rather than crystals, however this proved to be impossible. Because this change to the testing balloons was made a few days prior to final testing, students did not have enough time to practice with the crystal-filled balloons. Despite the fact that no group was successful in completely clamping and cutting the artificial organ, I do think they learned a great deal about the engineering design process and the difficulties in designing a device for minimally invasive surgery. In addition, I believe students have a new appreciation for the mastery a surgeon must have when performing one of these surgeries.