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Lesson Focus

This lesson focuses on surgical instrument design. Teams of students construct surgical instruments from everyday materials. They then test their surgical instruments to determine how well they can perform a simulated "surgical procedure".



Lesson Synopsis

The "Smooth Operator" lesson explores how surgical instruments are designed to assist medical professionals in conducting surgical procedures. Students work in teams of "engineers" to design and build their own surgical instrument out of everyday items. They test their surgical instrument, evaluate their results, and present to the class.

Age Levels

8-18.

Objectives

- ◆ Design and build a surgical instrument.
- ◆ Test and refine their designs
- ◆ Communicate their design process and results

Anticipated Learner Outcomes

As a result of this lesson students will have:

- ◆ Designed and built a surgical instrument
- ◆ Tested and refined their designs
- ◆ Communicated their design process and results

Lesson Activities

In this lesson, students work in teams of "engineers" to design and build their own surgical instrument out of everyday items. They test their surgical instrument, evaluate their results, and present to the class.

Resources/Materials

- ◆ Teacher Resource Documents (attached)
- ◆ Student Worksheets (attached)
- ◆ Student Resource Sheets (attached)

Smooth Operator

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Alignment to Curriculum Frameworks

See attached curriculum alignment sheet.

Internet Connections

- ◆ TryEngineering (www.tryengineering.org)
- ◆ How Robotic Surgery Will Work (<https://health.howstuffworks.com/medicine/modern-technology/robotic-surgery1.htm>)
- ◆ Liberty Science Center: Live From...Robotic Surgery (<https://lsc.org/education/for-teachers/live-from-surgery>)

Recommended Reading

- ◆ New How Things Work: From Lawn Mowers to Surgical Robots and Everything in Between (ISBN: 978-0792269564)

Optional Writing Activity

- ◆ Create a technical sheet for your new surgical instrument.

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For Teachers: **Teacher Resource**

◆ Lesson Goal

The goal of this lesson is for students to design and build a surgical instrument out of everyday materials. Their surgical instrument must be able to carefully pick up three small objects from a shoebox without knocking over any nearby dominos.

◆ Lesson Objectives

- ◆ Design and build a surgical instrument.
- ◆ Test and refine their designs
- ◆ Communicate their design process and results

◆ Materials

- ◆ Student Resource Sheets
- ◆ Student Worksheets
- ◆ Shoebox
- ◆ 3 small differently shaped objects (e.g. marshmallow, eraser, grape, noodle)
- ◆ Dominos or small rectangular blocks
- ◆ One set of materials for each group:
- ◆ Pencil, popsicle stick, plastic spoon, chopstick, construction paper, brass fasteners, string, paper clips, rubber bands, clothespins, binder clips, tape

◆ Procedure

1. Place the three small objects in the box and mark their location with a pencil.
2. Surround each object with dominos (standing up lengthwise). The dominos should be close to the objects but not touching them. Mark the position of each domino.
3. Before the lesson, ask students to name surgical instruments they may know. Discuss the role of engineers in designing medical devices.
4. Show students the various Student Reference Sheets. These may be read in class, or provided as reading material for the prior night's homework.
5. Divide students into groups of 2-3 students, providing a set of materials per group.
6. Explain that students must design a surgical instrument that can perform careful surgical procedures without disturbing any of the surrounding tissue or organs. They must remove 3 small objects from a shoebox without knocking over any of the dominos that surround them. All of the components of their surgical instrument must be physically connected. Materials such as pencils cannot be broken in half. All objects removed must remain intact for additional study by the medical team.
7. Students meet and develop a plan for their instrument. They agree on materials they will need, write or draw their plan, and then present their plan to the class.
8. Student groups next execute their plans. They may need to rethink their plan, request other materials, trade with other teams, or start over.
9. Teams then complete an evaluation/reflection worksheet, and present their findings.

◆ Time Needed

- ◆ One to two 45 minute class periods.

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Student Resource: Evolution of Surgical Instruments

◆ Engineering Biomedical Devices

Bioengineering or Biomedical Engineering is a discipline that advances knowledge in engineering, biology, and medicine — and improves human health through cross-disciplinary activities that integrate the engineering sciences with the biomedical sciences and clinical practice. Bioengineering/Biomedical Engineering combines engineering expertise with medical needs for the enhancement of health care. It is a branch of engineering in which knowledge and skills are developed and applied to define and solve problems in biology and medicine. Those working within the bioengineering field are of service to people, work with living systems, and apply advanced technology to the complex problems of medical care. Biomedical engineers may be called upon to design instruments and devices, to bring together knowledge from many sources to develop new procedures, or to carry out research to acquire knowledge needed to solve new problems. Major advances in Bioengineering include the development of artificial joints, magnetic resonance imaging (MRI), the heart pacemaker, arthroscopy, angioplasty, bioengineered skin, kidney dialysis, and the heart-lung machine.

◆ Brief History of Surgery

Surgery is the diagnosis and treatment of physical ailments or injuries by cutting bodily tissue with instruments. The word surgery comes from the Greek meaning “hand work”. Surgeries have been performed since prehistoric times. The first type of surgery to be performed was known as trepanation, or the process of making holes in the skull to relieve pressure and treat other types of ailments. Ancient Egyptians are believed to have performed dental and brain surgeries.

A man named Susrutha, who lived in 400 B.C. in what would be present day India, is often considered the father of surgery. He is believed to have performed several different types of surgical procedures, even rhinoplasty (cutting off the nose was a form of punishment during these times)! His writings known as the Susrutha Samhita have become a very important part of medical history.

Until the 16th century surgeries such as amputations and bone settings were performed by surgeons who were often also the town barber! During the 16th century the work of Leonardo da Vinci and Andreas Vesalius helped shed light on the human anatomy which was critical to the evolution of surgery. The introduction of anesthetics and sterilization in the 19th century helped make surgery much safer. Advancements such as blood typing, x-rays and lasers during the 20th century helped shape surgery as we know it today.

◆ Traditional Surgical Instruments

During surgery a number of different types of tools and instruments are utilized. Foam positioners may be used to get a patient’s body into the proper position for surgery. After anesthesia has been administered, different types of cutting instruments may be used to make incisions in the body or to get through bone. These may include instruments such as scalpels and drill bits.

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Student Resource (continued): Evolution of Surgical Instruments

After an incision has been made, an instrument known as a retractor may be used to hold open an incision while a surgical procedure is being performed. If surgery is being performed on a joint, an instrument known as a distractor may be used to open up the space between the two bones at the joint, giving the surgeon room to work. Other tools known as dilators and specula may be used to open up narrow passageways within the body so the surgeon is able to access these areas. A device known as forceps may be used during a surgical procedure to manipulate body parts.



Syringes and suction devices are used to introduce and remove fluids from the body respectively. Sometimes during surgery blood vessels or organs need to be clamped using devices known as clamps or occluders. If measurements of any kind need to be taken during surgery, instruments such as rulers or calipers may be used. After surgery has been completed, incisions are sewn shut with stitches or closed with instruments such as surgical staplers.

In addition to these basic surgical instruments a variety of technological equipment is also used during surgical procedures. Imaging systems may be used to guide the surgeon during a procedure. During certain surgeries, lasers may be used to close off nerve endings or blood vessels or remove tumors. A piece of equipment known as a cryotome may be used to freeze and preserve sections of tissue for later examination.

◆ Minimally Invasive Surgical Instruments

During the 1980's medical professionals began using a technique minimally invasive techniques to perform surgeries on their patients. Minimally invasive surgery also known as endoscopy or laparoscopy was intended as a way to perform surgical procedures with the least possible amount of trauma to a patient. Minimally invasive surgery involves inserting small fiber optic cameras called endoscopes or laparoscopes into tiny incisions in the patient's body to help guide surgeons during a procedure. A pointed cylindrical cutting instrument known as a trocar may be used to make small incisions and introduce laparoscopic instruments. Additional instruments may be used to guide and carry the cameras through the body.

Although laparoscopic surgery has numerous benefits, it has some limitations. One drawback is that a surgeon is only able to view images of the procedure on a two dimensional screen. Another limitation is that due to the kinds of instruments required for these procedures, the surgeon has a somewhat restricted range of motion when performing laparoscopic surgery.

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***Student Resource (continued):
Evolution of Surgical Instruments***

◆Surgical Robots

Robots began to be used for surgical purposes during the mid-1980's. The first robotic surgical procedure occurred in 1985 when a robot known as the PUMA 560 was used during a brain biopsy. Subsequent surgical robots were used to perform prostate surgery and hip replacements. In the late 1990s, the da Vinci Surgical System was introduced. The system is comprised of three main components: a console for the surgeon, 4 arms which can be controlled remotely, and a high definition 3 dimensional system. Each of the robotic arms possesses moveable surgical instruments which can be controlled by the surgeon. The instruments enter the body through flexible tubes known as cannulas.

The surgical system has the ability to scale the surgeon's hand movements and filter out any tremors to create precise movements. A camera captures the surgery which is then shown on the surgeon's console in 3D. The da Vinci system is used in the United States and Europe for hysterectomies, prostate cancer surgery, and mitral valve repair.

There are a number of benefits as well as drawbacks to robotic surgery. Robotic surgery can be performed remotely, which is useful when there may be a lack of skilled professionals in a particular location. Robotic surgery also has the benefits of using tinier incisions, resulting in faster healing time for patients. The surgical robot arm has much greater articulation than a surgeon would normally have giving the surgeon greater flexibility. The 3D imaging system also gives the surgeon enhanced visibility. Drawbacks to robotic surgery include the level of training needed to operate the system and the high cost of acquiring a robotic surgical system.



Student Worksheet:
Design a Surgical Instrument

You are a team of engineers who have been given the challenge to design a surgical instrument. This instrument will need to be able to perform very precise surgical procedures without disturbing any of the surrounding tissue or organs. To test your surgical instrument you will need to remove 3 small objects from a shoe box without knocking over any of the dominos in the box. All of the components of your surgical instrument must be physically connected. Materials such as pencils cannot be broken in half. All objects removed must remain intact for additional study by the medical team.

◆ Planning Stage

Meet as a team and discuss the problem you need to solve. Then develop and agree on a design for your surgical instrument. You'll need to determine what materials you want to use.

Draw your design in the box below, and be sure to indicate the description and number of parts you plan to use. Present your design to the class.

Design:

Materials Needed:

You may choose to revise your teams' plan after you receive feedback from class.

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For Teachers:**Alignment to Curriculum Frameworks**

Note: Lesson plans in this series are aligned to one or more of the following sets of standards:

- U.S. Science Education Standards (http://www.nap.edu/catalog.php?record_id=4962)
- U.S. Next Generation Science Standards (<http://www.nextgenscience.org/>)
- International Technology Education Association's Standards for Technological Literacy (<http://www.iteea.org/TAA/PDFs/xstnd.pdf>)
- U.S. National Council of Teachers of Mathematics' Principles and Standards for School Mathematics (<http://www.nctm.org/standards/content.aspx?id=16909>)
- U.S. Common Core State Standards for Mathematics (<http://www.corestandards.org/Math>)
- Computer Science Teachers Association K-12 Computer Science Standards (<http://csta.acm.org/Curriculum/sub/K12Standards.html>)

◆ **National Science Education Standards Grades K-4 (ages 4 - 9)**

CONTENT STANDARD A: Science as Inquiry

As a result of the activities, all students should develop

- ◆ Abilities necessary to do scientific inquiry

CONTENT STANDARD C: Life Science

As a result of the activities, all students should develop an understanding of

- ◆ Characteristics of organisms

CONTENT STANDARD E: Science and Technology

As a result of the activities, all students should develop an understanding of

- ◆ Abilities of technological design
- ◆ Understanding about science and technology

CONTENT STANDARD G: History and Nature of Science

As a result of the activities, all students should develop understanding of

- ◆ Science as a human endeavor

◆ **National Science Education Standards Grades 5-8 (ages 10 - 14)**

CONTENT STANDARD A: Science as Inquiry

As a result of the activities, all students should develop

- ◆ Abilities necessary to do scientific inquiry

CONTENT STANDARD C: Life Science

As a result of the activities, all students should develop an understanding of

- ◆ Structure and functions in living systems

CONTENT STANDARD E: Science and Technology

As a result of the activities, all students should develop an understanding of

- ◆ Abilities of technological design
- ◆ Understanding about science and technology

CONTENT STANDARD G: History and Nature of Science

As a result of the activities, all students should develop understanding of

- ◆ History of science

◆ **National Science Education Standards Grades 9-12 (ages 14-18)**

CONTENT STANDARD A: Science as Inquiry

As a result of the activities, all students should develop

- ◆ Abilities necessary to do scientific inquiry

CONTENT STANDARD C: Life Science

As a result of the activities, all students should develop understanding of

- ◆ Matter, energy and organization in living systems

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For Teachers:

Alignment to Curriculum Frameworks

◆ National Science Education Standards Grades 9-12 (ages 14-18)

CONTENT STANDARD E: Science and Technology

As a result of the activities, all students should develop an understanding of

- ◆ Abilities of technological design
- ◆ Understanding about science and technology

CONTENT STANDARD G: History and Nature of Science

As a result of the activities, all students should develop understanding of

- ◆ Historical perspectives

◆ Next Generation Science Standards Grades 3-5 (Ages 8-11)

Engineering Design

Students who demonstrate understanding can:

- ◆ 3-5-ETS1-1. Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials/time/cost.
- ◆ 3-5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet criteria/constraints of the problem.
- ◆ 3-5-ETS1-3. Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

◆ Next Generation Science Standards Grades 6-8 (Ages 11-14)

Engineering Design

Students who demonstrate understanding can:

- ◆ MS-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

◆ Next Generation Science Standards Grades 9-12 (Ages 14-18)

Engineering Design

Students who demonstrate understanding can:

- ◆ HS-ETS1-2. Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

◆ Standards for Technological Literacy - All Ages

Design

- ◆ Standard 8: Students will develop an understanding of the attributes of design.
- ◆ Standard 9: Students will develop an understanding of engineering design.
- ◆ Standard 10: Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.
- ◆ Standard 14: Students will be able to develop an understanding of and be able to select and use medical technologies.

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