Tennis Anyone?

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Lesson Focus

Lesson focuses on sports engineering and advanced materials development. Students work in a team to devise a racquet out of everyday materials that can consistently hit a ball to a target. Students design their racquet on paper, build the racquet, and test it. All teams evaluate their results, reflect on their design, and present to the class.

Lesson Synopsis

The "Tennis Anyone" lesson explores how engineers who work in the sports industry apply the latest materials, manufacturing techniques, and shapes to enhance sporting -- while maintaining the rules of a sport. Students work in teams to design a racquet made out of everyday materials that can consistently hit a ball to a target. They sketch their plans, consider material selection, build their racquet, test it, reflect on the challenge, and present their experiences to their class.

Age Levels

8-18.

Objectives

- Learn about engineering design and redesign.
- Learn about materials engineering.
- Learn how engineering can help solve society's challenges.
- Learn about teamwork and problem solving.

Anticipated Learner Outcomes

As a result of this activity, students should develop an understanding of:

- materials
- engineering design
- sports engineering
- teamwork

Lesson Activities

Students explore how engineers have incorporated the latest materials and manufacturing techniques to improve the performance of sports equipment. Students work in teams to construct a functional racquet out of everyday materials that can consistently hit a ball to a target. Students reflect on the experience and share with the class.

Resources/Materials

- Teacher Resource Documents (attached)
- Student Resource Sheet (attached)
- Student Worksheet (attached)

Alignment to Curriculum Frameworks

See curriculum alignment sheet at end of lesson.

Internet Connections

- TryEngineering (www.tryengineering.org)
- International Tennis Federation Racquet History and Manufacturing Process (https://www.itftennis.com/technical/rackets-and-strings/overview.aspx /)
- International Tennis Hall of Fame & Museum (www.tennisfame.com)

Recommended Reading

- The Physics and Technology of Tennis (ISBN: 978-0972275903)
- Technical Tennis: Racquets, Strings, Balls, Courts, Spin, and Bounce (ISBN: 978-0199557684)

Optional Writing Activity

- Write an essay or a paragraph about how the use of titanium has impacted the sports of golf, table tennis, and other sports. How has titanium use by engineers impacted other industries?

For Teachers: Teacher Resource

Lesson Goal

The "Tennis Anyone" lesson focuses on sports engineering and advanced materials development. Students work in a team to devise a racquet out of everyday materials that can consistently hit a ball to a target. Students design their racquet on paper, build the racquet, and test it. All teams evaluate their results, reflect on their design, and present to the class.

Lesson Objectives

- Learn about engineering design and redesign.
- Learn about materials engineering.
- Learn how engineering can help solve society's challenges.
- Learn about teamwork and problem solving.

Materials

- Student Resource Sheets
- Student Worksheets
- Classroom Materials: ping pong ball covered in hook and loop or Velcro; target board of cloth or Velcro with scoring boxes.
- Student Team Materials: pipe cleaners, bendable aluminum wire, straws, paper towel tubes, paper clips, tape, balloons, glue, string, foil, plastic wrap, pens, pencils, paper, other items available in the classroom.

Procedure

1. Show students the student reference sheets. These may be read in class or provided as reading material for the prior night's homework.
2. To introduce the lesson, consider asking the students how the tennis racquet has evolved over time. Ask them to think about how engineers incorporate newer materials or manufacturing processes to change and improve the performance or durability of a product.
3. If the internet is available, have students review the resources on the history and manufacturing of tennis racquets on the International Tennis Federation website (http://www.itftennis.com/technical/rackets-and-strings/overview.aspx/).
4. Students will work in teams of 3-4 students and consider their challenge. They'll also conduct research into how tennis racquets are manufactured online if possible.
5. Teams then consider available materials and develop a detailed drawing showing their racquet design including a list of materials they will need to build it.
6. Students build their racquet, and test it under teacher supervision. Each racquet must be able to direct a ping pong ball that has been covered in hook and loop (Velcro) onto a cloth or board with a target drawn on it. Team scores are based on highest scores on the target.
7. Students should observe the materials used and the design of other teams and gauge their performance.
8. Teams reflect on the challenge, and present their experiences to the class.

Time Needed

Two to three 45 minute sessions.

Student Resource: History of Racquet Design

◆ Racquet History

Tennis racquets have been made throughout the years in a variety of shapes, sizes, and out of many different materials. For the first 100 years of the modern version of the game of tennis, racquets were made of wood while strings were created from animal gut.

Originally, the size of the racquet was limited by the strength and weight of the wooden frame which had to be strong enough to hold the strings and yet stiff enough to hit the ball. Next, laminated wood construction yielded more strength in racquets, and were used through most of the 20th century. Manufacturers then started adding non-wood laminates to wood racquets to improve stiffness. Non-wood racquets were made first of steel, then of aluminum, and then carbon fiber composites. More recently, ceramics and lighter metals such as titanium were introduced. These engineered materials are stronger and enable the production of oversized rackets that offered more power during play.

Gut has partially been replaced by synthetic materials including nylon, polyamide, and other polymers. These engineered materials have proved to be more durable than the animal gut versions.

◆ Constraints of the Rules

Under modern rules of tennis, racquets must adhere to a certain set of guidelines or standards, to make sure that play is fair. These are some sample guidelines:

* The hitting area, composed of the strings, must be flat and generally uniform.
* The frame of the racket shall not exceed 73.7 cm (29.0 inches) in overall length, including the handle.
* The frame of the racket shall not exceed 31.7 cm (12.5 inches) in overall width.
* The hitting surface shall not exceed 39.4 cm (15.5 inches) in overall length, and 29.2 cm (11.5 inches) in overall width.
* The racquet must not provide any kind of communication, instruction or advice to the player during the match.

Engineers must work closely with those governing the rules of play to make sure that sporting equipment meets the requirements of the game.

Student Worksheet: Build a Racquet

◆ Research and Planning

You are part of a team of engineers who have been given the challenge of designing a tennis racquet out of everyday materials that can consistently hit a ball to a target. Read the handouts provided to you by your teacher, and if you also have access to the internet visit the International Tennis Federation at https://www.itftennis.com/technical/rackets-and-strings/overview.aspx to gain more understanding about the history and design of tennis racquets.

◆ Design Phase

You have been provided with many materials from which to design and build your own tennis racquet. Your racquet must be strong enough to stay together throughout the challenge. In the box below draw a diagram of your racquet and provide a list of the materials you plan to use.

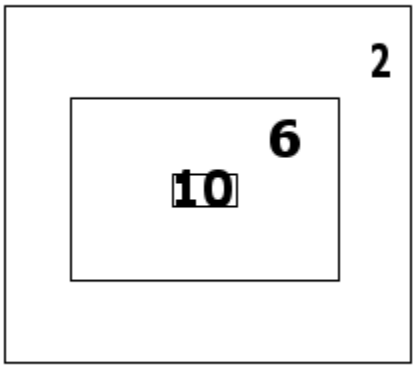
Materials List:

Student Worksheet:
Build a Racquet (continued)

◆ Building Phase
Build your racquet according to your plan…but you may adjust it in the manufacturing process. You may also request additional materials, or trade materials with other student teams. If you make revisions to your design, consider why you are making a change.

◆ Testing Phase
Try out your racquet! You'll use your racquet to hit a ping pong ball that has been covered in hook & loop or Velcro toward a target. Your goal is to use your racquet to hit your ball in the bullseye (or as close to the center as possible for highest points). Each member of your team may try the racquet up to three times -- and the six highest scores will be used to determine your team score. This way, if one team member has better aim than another, it will not matter.

During this phase, be sure to examine all the different designs of racquets created by all the teams in your class. There is no right or wrong way to complete this challenge, and much can be learned by observing the engineering ideas of other teams.



◆ Scoring
The center of the target is worth 10 points, the middle area is worth 6, and the outer area is worth 2.

Remember to only include your top six scores in the table below:

Score 1	Score 2	Score 3	Score 4	Score 5	Score 6	Total

If your racquet falls apart during testing, you'll take the scores you accumulated until it was unusable, and add zeros if fewer than six scores were achieved.

Student Worksheet: Build a Racquet (continued)

◆ **Reflection**

Complete the reflection questions below:

1. How similar was your original design to the actual racquet your team built?

2. If you found you needed to make changes during the construction phase, describe why your team decided to make revisions.

3. Did your racquet survive the testing phase? If not, what would you have done differently in design or building to ensure it would have survived?

4. At the end of the testing phase, did your racquet experience significant damage? If so, what type of reinforcement would you have incorporated if you did this challenge again?

5. After the testing phase, what features would you have incorporated into a new design? What other materials might you have used?

6. Which racquet that another team made was the most effective or interesting to you? Why?

7. Do you think that this activity was more rewarding to do as a team, or would you have preferred to work alone on it? Why?

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 activities, all students should develop

- Abilities necessary to do scientific inquiry

CONTENT STANDARD B: Physical Science

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

- Properties of objects and materials
- Position and motion of objects

CONTENT STANDARD E: Science and Technology

As a result of activities, all students should develop

- Abilities of technological design
- Abilities to distinguish between natural objects and objects made by humans

CONTENT STANDARD F: Science in Personal and Social Perspectives

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

- Science and technology in local challenges

CONTENT STANDARD G: History and Nature of Science

As a result of 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 activities, all students should develop

- Abilities necessary to do scientific inquiry

CONTENT STANDARD B: Physical Science

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

- Properties and changes of properties in matter
- Motions and forces
- Transfer of energy

CONTENT STANDARD E: Science and Technology

As a result of activities in grades 5-8, all students should develop

- Abilities of technological design
- Understandings about science and technology

CONTENT STANDARD F: Science in Personal and Social Perspectives

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

- Science and technology in society

For Teachers: Alignment to Curriculum Frameworks

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

CONTENT STANDARD G: History and Nature of Science

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

- Science as a human endeavor
- Nature of science
- History of science

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

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop

- Abilities necessary to do scientific inquiry

CONTENT STANDARD B: Physical Science

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

- Motions and forces

CONTENT STANDARD E: Science and Technology

As a result of activities, all students should develop

- Abilities of technological design
- Understandings about science and technology

CONTENT STANDARD F: Science in Personal and Social Perspectives

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

- Science and technology in local, national, and global challenges

CONTENT STANDARD G: History and Nature of Science

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

- Science as a human endeavor
- Nature of scientific knowledge
- Historical perspectives

◆**Next Generation Science Standards Grades 2-5 (Ages 7-11)**

Matter and its Interactions

Students who demonstrate understanding can:

- 2-PS1-2. Analyze data obtained from testing different materials to determine which materials have the properties that are best suited for an intended purpose.

Motion and Stability: Forces and Interactions

Students who demonstrate understanding can:

- 3-PS2-1. Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.

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, or cost.
- 3-5-ETS1-2.Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

For Teachers: Alignment to Curriculum Frameworks

◆**Next Generation Science Standards Grades 2-5 (Ages 7-11)**

Engineering Design

Students who demonstrate understanding can:

- 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-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
- MS-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
- MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

◆**Standards for Technological Literacy - All Ages**

The Nature of Technology

- Standard 1: Students will develop an understanding of the characteristics and scope of technology.
- Standard 3: Students will develop an understanding of relationships among technologies & the connections between technology & other fields of study.

Technology and Society

- Standard 4: Students will develop an understanding of the cultural, social, economic, and political effects of technology.
- Standard 6: Students will develop an understanding of the role of society in the development and use of technology.
- Standard 7: Students will develop an understanding of the influence of technology on history.

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.

Abilities for a Technological World

- Standard 11: Students will develop abilities to apply the design process.

The Designed World

- Standard 19: Students will develop an understanding of and be able to select and use manufacturing technologies.