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The following lessons were created by **Sean McAndrews**, a teacher participating in the National Endowment for the Humanities Summer Institute for Teachers entitled Touch the Past: Archaeology of the Upper Mississippi River Region.

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Tool Making and the Physics of Projectiles

Grade Level 12

Subject Physics

Objectives

1. We will review what tools and technologies are, and explain some of the reasons why humans produce them.
2. We will review Newton's Laws of Motion, and we will discuss forces, acceleration, and motion, specifically projectile motion.
3. We will design an object to move a projectile the maximum possible distance and examine the forces placed on the object, and the relationships between the mass of the object, the distance it travels, and the force required.

Standards

1) **NGSS Standards**
   - **a. HS. Forces and Interactions**

     HS-PS2,1

     Analyze data to support the claim that Newton's second Law of Motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.

     Science and Engineering Practices
     Planning and Carrying Out Investigations
     Analyzing and Interpreting Data
     Using Mathematics and Computational Thinking
     Constructing Explanations and Designing Solutions
     Disciplinary Core Ideas
     PS2.A: Forces and Motion
     PS3.A: Definitions of Energy

ETS1.A: Defining and Delimiting an Engineering Problem
ETS1.C: Optimizing the Design Solution

b. HS. Engineering Design

HS-ETS1-1

Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

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.

Science and Engineering Practices

Asking Questions and Defining Problems
Constructing Explanations and Designing Solutions

Disciplinary Core Ideas

ETS1.A Defining and Delimiting Engineering Problems
ETS1.B Developing Possible Solutions
ETS1.C Optimizing the Design Solution

2) Common Core Standards

RST.11-12.7

Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (HS-PS2-1)

WHST.11.12.7

Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-PS2-3),(HS-PS2-5)

MP.2

Reason abstractly and quantitatively (HS-PS2-1), (HS-PS2-2), (HS-PS2-4)

MP.4

Model with mathematics (HS-PS2-1), (HS-PS2-2), (HS-PS2-4)

Duration

This lesson will require 1-2 weeks of class time plus some independent research and work by the students.

Materials

-A computer with internet access, a SMART Board or Promethean Board
-Paper, pencils, a calculator, measuring equipment
-Supplies for building an atlatl (if approved by administration)
These might include small diameter wooden poles, points for tips, wood and leather for making the dart thrower for the atlatl. (A kit for constructing the atlatl and darts could be purchased instead.)

-If not permitted to build real tools such as these at school, an online simulation program could be substituted, such as the projectile motion program at PhET: (http://phet.colorado.edu/en/simulation/projectile-motion), or a ball thrower, or NERF toy could be tested

Vocabulary
Projectile motion
Trajectory
Atlatl
Kinematics
Parabolic path

Background

The Next Generation Science Standards (NGSS) place increased emphasis on human sustainability, human impacts on earth systems; and engineering, technology, and applications of science. Forces and interactions are also covered by the NGSS.

I plan to incorporate more engineering challenges, human impacts on the world, and human tool and technology development into this class. Over the coming school year the students will carry out 1-2 projects each quarter where they will be required to design and test a device to accomplish a specific task.

These tasks will vary from simple 1 or 2 period challenges to multi-week lessons that will require them to develop an idea for an object, design it, test it, and re-design it to achieve the best possible result.

One source of inspiration for this project was an e-book published by NSTA press, called "Science by Design: Construct a Boat, Catapult, Glove, and Greenhouse" written in 2013.

At the time we start this lesson, the students should already know the basics of 1 and 2 dimensional kinematics. We will have completed several small projects and challenges, and will have already discussed some aspects of human civilization and engineering. We will have talked specifically about how we have become such a specialized culture that many people don't know how even relatively simple tools that they see in their everyday lives were engineered.

Setting the Stage

This lesson and the accompanying activities will fall partway through the first quarter, as we are covering the mechanics and kinematics parts of classical physics. We will be starting to discuss projectile motion, and will be working through problems related to that topic. We will have already introduced motion, forces, velocity, mass, and acceleration. We will have also talked a little about human tools and technology.

We will watch a video from the TED web site called "How I built a toaster — from scratch" presented by Thomas Thwaites (http://www.ted.com/speakers/thomas_thwaites): http://www.ted.com/talks/thomas_thwaites_how_i_built_a_toaster_from_scratch

I will then start a discussion with the class on what it might take to build a tool to get food for their families. We will focus on the time period before guns. My goal will be to get them to come up with 3 tools; spears, an atlatl, and a bow and arrow.

Procedure

1. On the first day we will cover the activities summarized in the Setting the Stage section above. We will discuss in what order they think the 3 projectile tools were developed, and what their advantages and disadvantages might have been. This may carry over into day 2. We will briefly discuss what an atlatl is, and how it was used.

2. The students will then be divided up into 2-4 groups and assigned the spear and the atlatl. They will be asked to work together to come up with a possible diagram to show how their assigned tools might be built. They will also need to come up with a list of possible supplies they might need to build them, and where those supplies could be obtained from.

3. The students will then be given class time, plus 1-2 nights (as homework) to research their assigned tools, plus the bow and arrow. They will prepare a short typed summary on the history and development of those tools plus their disadvantages and advantages. They will also need to brainstorm on how they might obtain the necessary materials to build their tools.

4. We will use 2-3 days of class time to discuss the variables used in calculating projectile motion, and the students will work some practice problems.

5. Each group would be supplied with materials, locally obtained if possible, to build an atlatl. They will use a simple pre-made bow for comparison instead of trying to build one. They will be given the chance to test their projectiles and re-design them if necessary.

6. Each group will develop some questions that they will test with their projectile tools. They may look at comparing their range or accuracy or difficulty using, or another question they develop.

7. With the administration's permission, we will set up a practice range out away from the school and set up a target. Each group will be given several practice throws with the atlatl and the bow. We will then set up a measuring tape and record distances and accuracy (distance from the target) for each tool. We will estimate the height each tool reaches at its apex. Data will be gathered by each group and used for later calculations.

NOTE: NERF toys or some other safer projectiles could be substituted.

8. The students will be given a day to analyze their data and complete their calculations. Using the acceleration and the mass of their projectile, they will attempt to measure the force applied.

9. They will prepare a lab report evaluating their design, comparing the tools, and researching their use in our area.

Closure

We will discuss tool making, projectile motion, and the engineering design process in light of what each group has done. Each group will have 3-5 minutes to summarize what they learned about projectile motion and the tools. Groups will produce and turn in a report on the project.

Evaluation

The students will be evaluated individually and in their groups based on their daily work, their tools produced, and their final reports. Specifically they will be required to turn in their diagrams and supply lists, their summaries with a list of at least 3-4 resources they consulted when researching their tools, their practice problems, and their research questions.

They will also be evaluated on the testing of their tools, their data gathered, and their calculations. Their completed tools, their final reports, and their 3-5 minute summaries will be their final grades.

Links/extensions

This lesson and the accompanying activities will be part of a year-long series of lessons and projects which will require the students to apply elements of design with physics concepts to research and produce tools which solve a problem or answer a question.

It could also be used as part of an interdisciplinary lesson or unit with a History or Social Studies teacher, or possibly with a shop/FFA instructor.

References

http://phet.colorado.edu/en/simulation/projectile-motion
http://www.nextgenscience.org/
http://www.ted.com/talks/thomas_thwaites_how_i_built_a_toaster_from_scratch
http://www.physicsclassroom.com/
http://www.atlatl.com/
-Windows into the Past: Crow Canyon Archeological Center's Guide for Teachers 2000 Edition. Edited by M Elaine Davis and Marjorie R Connolly
-Survival with the Atlatl Spiral-bound – January 1, 1987 by Bill Tate
-Twelve Millennia: Archaeology of the Upper Mississippi River Valley 2003 edition by James L. Theler and Robert F. Boszhardt

Resources

http://www.physicsclassroom.com/class/vectors/Lesson-2/What-is-a-Projectile
Explanations on projections, formulas, and practice problems

http://www.modelingphysics.org/2dmotion/practice.htm
Practice problems

http://www.aplusphysics.com/courses/regents/kinematics/regents_projectile_motion.html
Formulas and practice problems