Mathematics, Science and
Technology Partnership
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GUIDANCE FOR TEACHERS
Design Activity: Redesigning a Mousetrap Car
Suggested Activity Length: 3 weeks

Problem Situation: Many products exist that can be improved. Indeed, technological innovation is often the result of improving on the work of others. Automotive engineers have carefully improved such areas as engine design and aerodynamics to achieve better performance and gas mileage. In this problem situation, the power source for a small toy car is a mousetrap. It is a simple idea with lots of room for improvement.

Your Challenge: You and your teammates are to redesign a mousetrap car so that it will travel the greatest distance possible.

Objective: Students will gain an understanding of the redesign process, the role of friction in moving parts, and energy transfer from one system to another.

> *Note:* This activity results in several simple mousetrap cars. Students will investigate how to improve the design. In this instance, besting the teacher proves to be a great incentive for learning. You might consult or refer students to any of the Web sites featuring different types of mousetrap cars. You may also want to assign homework in which students investigate winning mousetrap car designs. See: http://www docfizzix.com
> http://www.mike.lanham.com/mousetrap/index2.html
> http://users.bigpond.net.au/mechtoys/mouse.html
> http://www.essentialschools.org/pub/ces_docs/resources/nyac/mineola/vision.html

KSB 1 -- Factors that affect the performance of the mouse trap car.

Rather than have the students design a mousetrap car from the ground up, you might consider giving them an imperfect model, already built. The advantage is that you can focus students on the variables that can affect the performance of the vehicle, and save time in the process. Clearly it's your choice, and if you wish to focus on open-ended design and have the time, you can give them a parts list and let them do their designing in design teams.

Think of the mousetrap car as a system with multiple subsystems. Each system can be optimized to maximize performance (in this case, the distance the car travels). Some of the subsystems are: The propulsion subsystem (the spring – however this system is not alterable in this challenge); the transmission subsystem (the extension rod and the string wrapped around the axle); the guidance and control subsystem. Prompt the students to think about the guidance and control (steering) subsystem. How can the wheels and axles be aligned to keep the car going straight?

KSB 2 -- The Relationship between force, speed, and distance traveled.

If students do not allow for enough string to ensure that the car runs freely with the lever arm down, the string will act as a brake on the axle. In this situation, increasing the lever arm length will increase the car's travel. The relationship between the force pulling on the axle and the distance the car travels is not intuitive. The measure of a force's tendency to produce a rotation about an axis (the twisting force) is called *torque*. The formula for torque (τ) is the radial distance (r) the rod travels, multiplied by the force (F), or **τ = r x F. Force, therefore =** τ/ r. The force is **inversely proportional** to the radial distance.

The students can see this as they try to hold the lever arm close to the spring or further away from the spring. The further away they get, the less force they will feel.

Stress, however, that the car cannot weigh too much or there won't be enough energy to move it. Similarly, if the lever arm moves too quickly, the axle and wheels may spin. Remind students that the goal is to maximize distance traveled, not speed. Changing the criteria by introducing speed, or speed over a certain distance, will yield additional tradeoffs to consider.

KSB 3 - Friction

This KSB allows students to investigate the role of rolling friction as friend and enemy. If you wish, use more sophisticated bushings than plastic straws, although these are inexpensive and serve the educational purpose. It is important to increase the friction between the wheels and the floor. Additional weight on the car can serve that purpose, as long as students avoid adding too much weight, which would result in extra work needed to move that car and less distance traveled. You can use large rubber bands or even cut up balloons to fit over the driving wheels to create friction between the wheel and the surface upon which it rolls.

KSB 4 –Size of the wheels

In KSB-4, students collect data that will show that the larger the driven wheel, the greater the distance the car travels because each rotation of the axle causes one rotation of the wheels. However, there will be some trade-offs. For instance, if the car's weight increases too much because of the larger wheels, or if there is increased axle friction, the gain from the greater wheel diameter is reduced. Often, the axle needs to be increased because there is not enough torque with a small diameter axle to rotate the wheel.

Students collect data in the table provided and will find that in every case, the distance for one revolution is just a bit more than 3 x the diameter of the wheel.

Students will do ratio calculations for several different wheel diameters and distances traveled (ratio of Distance/diameter). In the next KSB, KSB-5, the data will be used to derive a value for Pi (π). Then they can figure out the *average ratio* and will find that their answer approximates Pi (π) which equals 22/7 or 3.1428571. Some **sample data** is shown below.

Wheel	Diameter	Measured distance for one revolution	Ratio of distance traveled in one revolution to the wheel diameter (Distance/diameter)
Wheel # 1	1”	3 ¼”	3. 25
Wheel # 2	2”	6 ¼”	3.125
Wheel # 3	3”	9 ½”	3.166
Wheel # 4	4”	12 ½”	3.125

Knowledge and Skill Builder 5: Finding the circumference.

Mathematically speaking, the distance around a circle called the **circumference**. In this KSB, students will find the average relationship that exists between the circumference of their wheels and the wheel diameters. Using the sample data show in the table above (related to KSB-4), the average would be the sum of 3.25 + 3.125 + 3.166 + 3.125 = 12.666 / 4 = 3.1665, very close to the value of Pi. The formula for the circumference of a circle is $C = \pi D$.

Knowledge and Skill Builder 6: Testing different diameter wheels.

The new mathematical element that is added here, is that of making predictions – not guesses, but informed predictions based on what the students learned in KSBs 4 and 5. Their predictions should take into account that fact that the distance traveled would be about 3 x the diameter of the driving wheel.

Note: Help encourage the students to do Mathematical reasoning:

If we use the same length of string and the same axle diameter, then the number of axle rotations won't change when you change the wheel diameter.

Since the number of axle rotations is the same, the distance traveled will be greater with a wheel of larger circumference. The distance the car will travel will be πD multiplied by the number of axle rotations.

To determine how far the vehicle is going to travel, we need to know the number of axle rotations, and also the circumference of the wheel.

Design Solution/Test and Evaluation

Students should discover that the car must travel in a straight line to achieve the greatest distance traveled. You may want to allow them the best of two attempts. Except for friction, the effect of small wheels on the nondriven axle should have no effect on the design.

Redesign

Focus student attention on the energy that comes from the energy of the spring and the lever arm movement. The total work that can be provided to the car cannot exceed the spring's energy. Work is force times distance. When the lever arm is long, the force it exerts on the string is smaller than when the lever arm is short. The product for force times distance will be the same, however: short arm, high force acting through short distance or long arm, low force acting through long distance.

Implementation Plan

Period	Focus Model Component (For Teacher)	Informed Design Loop Component (For Student)	Activity
1-2	Focus Discussion on Problem Context	Clarify Design Specifications and Constraints	Begin Discussion of Module Overview
2	Organize for Informed Design		Discussion of Design Process and Recording/Reporting Requirements
3-9	Coordinate Student Progress	Research and Investigate	Conduct KSB 1-Factors that affect the performance of the mouse trap car Conduct KSB 2-Relationships among force, speed, and distance traveled. Conduct KSB 3-Friction Conduct KSB-4 – Size of the wheels Conduct KSB-5 – Finding the circumference Conduct KSB-6- Testing different diameter wheels
10	Coordinate Student Progress	Generate Alternative Designs	Create Sketches and/or Models of Alternative Design Solutions
10	Coordinate Student Progress	Choose and Justify Optimal Design	Select and Defend Choice of Preferred Alternative Solution
11-13	Coordinate Student Progress	Develop a Prototype	Develop Plans for Construction, Build Model, and Create Visuals and Resources List
14	Unite Class Thinking about Accomplishments	Test and Evaluate the Design Solution	Develop Plans for Testing and Test the Design Solution
15	Evaluate Student Learning	Redesign the Solution	Respond to Questions
16	Sum Up Progress on Learning Goals	Communicate Your Achievements	Class Presentations of Methods and Results