ScienceNews

Activity Guide for Students: Building Better Boxes Based on Beetles

Directions:
In this activity, you will study the physical characteristics that make the diabolical ironclad beetle almost indestructible. You will work in groups and use information about the beetle's exoskeleton to design packaging that resists damage. Then, your group will construct a prototype (preliminary model) and test its strength. As a class, you will discuss which prototypes performed best and why.

The setup
After reading the online *Science News* article "The diabolical ironclad beetle can survive getting run over by a car. Here's how," answer the following questions as part of your homework.

1. Describe two features of the beetle's anatomy that make the beetle so difficult to crush.

2. How do the structures you identified prevent the beetle's exoskeleton from being crushed?

Class discussion
With your class, review information about forces and Newton's laws of motion. Discuss with the class how those scientific principles apply to the diabolical ironclad beetle's ability to resist crushing. Then, answer the following questions as a class.

1. Draw a force diagram that shows the size and direction of forces exerted on a diabolical ironclad beetle's body when the beetle is stepped on by a 60 kg (588 N) animal. Assume that the beetle's mass is about 2 grams, so it exerts a force on the ground of 0.2 N.

2. Explain how features of the diabolical ironclad beetle's exoskeleton change the direction and/or magnitude of the forces exerted on its body when it is stepped on.

3. Modify your force diagram to incorporate information from your answer to the previous question. You may need to add, remove or modify the size or direction of arrows in your diagram.

Defining the problem
After your class discusses how the diabolical ironclad beetle's exoskeleton structure is a solution to a problem, consider the following scenario:

Many products and materials are shipped throughout the world. Many shipments arrive damaged as a result of compressive forces that result from containers being stacked or from impacts or collisions during transit.

Based on this scenario, answer the following questions as a class.

1. What engineering problem will your container design address?

2. What criteria, or requirements, would your solution need to meet in order to be successful? How would you know if your solution met these requirements?

3. What constraints would limit the success of your solution? Think about how the solution's cost, its ease of use and other restrictions will affect how it could be used.

4. How could you test designs or prototypes to see if the criteria and constraints of the problem have been met? How could you measure results to compare design options?

Designing a solution
Work with your group to clearly state the design problem and list the criteria and constraints for a successful solution. Answer the following questions with your group.

1. Brainstorm solutions for the engineering design problem you described. Use information about the diabolical ironclad beetle's exoskeleton to guide your design. Sketch drawings using force diagram arrows to design possible solutions.

2. As a group, choose the solution you think best solves the problem while meeting all the criteria and constraints. Describe that solution.

3. Create a sketch or a physical or computer model of the chosen solution. Include a force diagram that demonstrates how you think your solution will change the forces on the container.

Evaluating solutions

Have your teacher review and approve your group's design and force diagrams before starting your group's prototype. Adapt your design as needed based on feedback from your teacher. Present your group's design to the class and explain how it will solve the engineering problem. Answer questions from your class about your group's design and provide feedback to other groups. After all groups have presented their designs, answer the following questions as a class.

1. Which structural features were most common among the different designs, and why were those features incorporated by multiple groups into their engineering solutions?

2. Which design or designs are the most promising for solving the design problem while meeting all the criteria and constraints?

3. As a group, modify your proposed design to improve its capacity to resist crushing. You will use the optimized design to build a prototype to test for durability. Describe that the modified design and create a sketch or model of that design. Sketches or models of the design should include information about the prototype's dimensions, construction and composition.

Constructing and testing a prototype

Work with your group to construct and test your prototype for strength and durability. As a group, answer the following questions.

1. Think about how to measure the amount of weight or force a box can withstand. Describe the method you will use to test how well your prototype resists crushing. Identify any measurements you will take or any observations you will record.

2. With your group, construct one or more prototypes of your design that you will test using the method you outlined. Note any issues you had or any changes you made to the design while constructing the prototypes.

3. Test your prototype to see how well it resists crushing. Record your observations.

4. How did your prototype perform? Did it resist crushing, or did the box deform or fail to support the weight?

Analyzing and optimizing a solution
After all prototypes have been tested, report the results of your group's tests to the class. As a class, answer the following questions.

1. Which prototype(s) performed the best in the tests? Which performed the worst?

2. What elements of the successful designs made them more resistant to crushing than the others? Support your answer with evidence and scientific reasoning.

3. How were the properties of the diabolical ironclad beetle's exoskeleton expressed in the final container prototype?

4. What other properties of a shipping container might engineers want to think about when designing packaging materials that are resistant to crushing forces?

5. Based on the outcome of the tests, how would you alter the design of the best-performing prototype to further improve on the strength or durability of your container?