Drexel-SDP GK-12 ACTIVITY

Activity: Play Ball

Subject Area(s) Data Analysis & Probability, Measurement, Number & Operations, Physical Science

Associated Unit Vital Mechanics

Associated Lesson Biomechanics

Activity Title Play Ball

Angles and mechanics play a large role in sports.

Grade Level 7 (6-12)

Activity Dependency

Time Required 45 minutes

Group Size 3 people

Expendable Cost per Group US $3

Summary

Students will have the opportunity to investigate how angles play a role in baseball by measuring dimensions of a baseball diamond and tracking the throwing motion of the arm.

Engineering Connection

As the film clips in the **Biomechanics** lesson illustrated, position and form play a large role in the success of those throwing a baseball. This concept applies not only to baseball but other sports (golf, basketball, tennis, running) or events (injury analysis, crash testing). In order to analyze a biomechanical problem, researchers will collect data (motion analysis). Motion is analyzed by objects *translating* or *rotating* in a particular *reference frame*. This frame of reference may be 2-D or 3-D, and motions involving rotations are classified in terms of angles relative to the reference frame.

Keywords

biomechanics, mechanics, angle, baseball, throw, motion, geometry

Educational Standards

- PA Science:
  - 3.1.7 – Unifying themes
  - 3.2.7.B – Apply process knowledge to make and interpret observations
- PA Math:
  - 2.1.8.D – Apply ratio and proportion to mathematical problem situations involving distance, rate, time, and similar triangles
  - 2.4.5.B – Use models, number facts, properties, and relationships to check and verify predictions and explain reasoning
  - 2.5.8.B – Verify and interpret results using precise mathematical language, notation and representations, including numerical tables and equations, simple algebraic equations and formulas, charts, graphs, and diagrams
  - 2.7.8.D – Compare and contrast results from observations and mathematical models
  - 2.8.8.B – Discover, describe, and generalize patterns, including linear, exponential, and simple quadratic relationships

Pre-Requisite Knowledge

Accompanying lesson, **Biomechanics**.

Learning Objectives

After this activity, students should be able to:

- Identify role of angles in baseball
- Describe how motion capture allows for computation of angles
- Describe how angles relate to position in a 2-D scenario
- Predict how releasing the ball early or late will affect a ball's trajectory and final position

Materials List

Each group needs:

- 1 baseball glove (check with physical education instructor)

- 1 one-meter measuring tape
- Rubber markers for mound, home plate (optional)

To share with the entire class:

- "Play Ball" worksheet
- 1 hundred-foot measuring tape

Introduction / Motivation [segue from **Biomechanics** lesson]

Baseball is a game that is strongly influenced by angles. Let's take a look at some of these.

[geometry]

Draw a baseball diamond on the board. The playing field is anchored to a diamond structure with 3 bases and "home plate." What are the distances between the bases? *60' in Little League, 90' in older leagues. {Sketch out the distances on the board and draw lines in between home and 2nd base, 1st and 3rd base.}* What kind of triangle is made by a line segment connecting 1st and 3rd base along with the 1st and 3rd baselines? *Isoceles*. What kind of triangle is made by a line from home to 1st base, 1st base to 2nd base, and 2nd base to home plate? *Isoceles again.* Are these triangles different? *No – based on equal base path distance. {Erase the line between 3rd base and 1st base.}* How would we find the distance between 2nd base and home plate? *Similar triangles – use Pythagorean theore: relation of "diamond" – square rotated 90º.* Why must catchers and 3rd basemen have strong throwing arms? *They must make the farthest throws among infielders.*

[trajectory]

{Erase 'geometry' on board}. Let's consider the angle that the bat makes with the ball. Remember how contact angle mattered in the **Collisions** activity? What happens if you swing at the ball and there is a large angle (135º degree with respect to vertical, with clockwise rotation, for right-handed batter) between your body and the bat? *Show hand position and simulated swing. End result is called "golfing" the ball, and a pop-up occurs, which can be easily fielded.* What happens if there is a low angle (45º degree with respect to vertical, with clockwise rotation, for right-handed batter) between your body and the bat when you swing at the ball? *Show "chopping at the ball" – if you swing like this, likely result is an easily fielded, weak ground ball.* So for anyone who plays baseball or softball, what does your coach tell you? *Swing level.* This is why some coaches train with hitting off of tees (at high school levels) – to train your body to swing level. What's likely to occur if you swing level (~90º degree with respect to vertical, clockwise rotation, for right-handed batter)? *You're more likely to hit the ball into a hard line drive or ground ball which is difficult to field.*

[technique]

You must train your body to achieve and consistently repeat proper technique. There are the batting drills that train for level swings and throwing drills that emphasize proper throwing form like you saw in the video clip. Body position strongly relates to proper pitching technique. The instructor analyzed reference points on the body (shoulder, hip, knee) using angles to demonstrate this. In addition, infielders are typically drilled to increase muscle memory and improve coordination. There are sequential steps to generate momentum for a throw using your body weight. *For a right-handed person, hold ball with "crescent" of space between palm and ball; cock arm backwards, with feet in line - left foot in front of body and right foot behind body; drive arm forward and release ball while moving right leg from behind body to in front of left leg.*

Where does a pitcher line up to throw *(not in Little League)*? *A mound.* Why is it called a "mound"? *Raised area on the field.* When pitchers throw at high speeds over long distances, they need a lot of forward momentum, which they achieve by pushing forward (with their legs) from the mound. This underscores the importance of pitchers keeping their legs in shape to increase endurance. Otherwise, how does a mound change the geometry of the field for a pitcher trying to throw a ball in the strike zone? *Changes the necessary release angle.*

[data collection]

Motion capture devices allow us to record and play back this sequence of events for frame-by-frame analysis. Since we don't have the setup for that in the classroom, we're going to use the low-tech approach of a "spotter." When we go [outside / to the gym] you will form groups of three, in which that people can rotate in and out to (1) pitch, (2) spot the ball's release point for the pitcher, and (3) catch the ball thrown from the pitcher.

While the pitcher is holding the ball, the spotter should measure (1) distance from ground to pitcher's shoulder, (2) distance from pitcher's shoulder to ball, and (3) horizontal distance from pitcher's shoulder to point that intersects a vertical line dropped from ball's release point. These measurements should be recorded on each pitcher's worksheet. Multiple throws may be required for the spotter to determine a pitcher's release point.

Vocabulary / Definitions

Word	Definition
Biomechanics	Study of mechanics (forces and deformation due to forces) in a biological system. Typical *biomechanical* systems involve flow of gases and liquids as well as motion of bones due to muscle contraction.
2-D	Two-dimensional. In geometry, a plane is two-dimensional. Typical axes are x and y.
3-D	Three-dimensional. Most motion doesn't occur in a plane, therefore it is *3-D* and characterized by 3 axes: x, y, and z.
Motion capture	The method used to gather data (still frames from video) for biomechanical analysis. One camera is sufficient for 2-D analysis, but two or more cameras placed at different angles must be used for 3-D analysis of the region of interest. Reference points may be placed in the video region (2-D or 3-D grid) or on the subject to quantify angles and motion.

Associated Activities

Ramped Up

Attachments

vital_mechanics_activity_playball_worksheet.pdf

Safety Issues

- Instruct students to spread out and throw in the same direction, away from groups of students and streets.
- Students with gloves should not throw balls at full speed to those without gloves; balls should be tossed so that they roll in front of students without gloves.

Investigating Questions

What is the release angle when throwing a ball?

How might this change on a mound?
Why aren't mounds used in Little League baseball or softball?

Procedure

Background

Show demonstration about taking measurements on board (**Introduction/Motivation**) in conjunction with worksheet.

Before the Activity

- Distribute worksheet.
- Set up "pitching" stations – "mound" and "home plate" markers 40 feet apart (or the standard distance for the age group league), with a measuring tape at each station

With the Students

1. For a 3-person group, demonstrate roles of pitcher, motion tracker, and catcher.
    a. Show proper measurement steps
    b. Rotate positions.
2. Assist with questions about measurement data.
3. Perform angle calculations during lesson wrap-up in classroom.

Assessment

[release angle - see worksheet]

Wrap-up with a discussion about how the measurements allow calculation of a release angle. We form a triangle from the distance from shoulder to ball (diagonal), with horizontal and vertical components. We measured the horizontal component. By using a trigonometric relation called the cosine function, we can compute the included angle with a calculator.

$$\cos\theta_1 = \frac{\text{length of adjacent side}}{\text{length of hypotenuse}} = \frac{l_3}{l_2}$$

$$\theta_1 = \cos^{-1}\left(\frac{l_3}{l_2}\right)$$

[release angle with mound]

We computed the release angle θ_1 (between our arm and the ground) for throwing on level ground. Will our release angle change if we are throwing from a mound? *Yes. We must consider the height of the mound.* Under Major League Baseball rules, the peak of the mound must be no more than 10 inches (25.4 cm) higher than home plate (WikiAnswers). The release angle of the ball relative to home plate can be calculated for the low (θ_2) and high (θ_3) bounds of the strike zone (knees to mid-torso on average-height student) in a bigger triangle involving the mound:

$$\tan\theta_2 = \frac{\text{length of adjacent side}}{\text{length of opposite side}} = \frac{d_{\text{mound}} - l_3}{l_2\sin\theta_1 + l_1 - l_4},$$

$$\theta_2 = \tan^{-1}\left(\frac{d_{\text{mound}} - l_3}{l_2\sin\theta_1 + l_1 - l_4}\right),$$

$$\theta_3 = \tan^{-1}\left(\frac{d_{\text{mound}} - l_3}{l_2\sin\theta_1 + l_1 - l_5}\right).$$

The variable d_{mound} represents the distance between the back of home plate and the mound: 47 feet (14.33 meters) for Little League and 61'6" (18.75 meters) for older leagues; l_1, l_2, l_3 are

distances calculated from the activity for each pitcher; and l_4 represents the distance from the floor to the knees of a student; and l_5 represents the distance from the floor to a student's mid-torso. The corresponding change in angle for a ball that follows a straight path when pitched is

$$\Delta\theta = \theta_2 - \theta_3 .$$

Activity Scaling

- For lower grades, focus on measurement and explain how to calculate angles.
- For upper grades, encourage completion of worksheet as **Assessment**.

Owner

Drexel University GK-12 Program

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