5.1: Altitude and Azimuth – Your Place in the Sky

The focus of this activity is to teach students to use some simple tools, a compass and a protractor. The compass will be used to measure bearing or ***azimuth*** of a distant object such as a tree or telephone pole. The protractor will be used to measure the angle between the horizon and the distant object, this is also called the ***altitude***. The protractor is not the plastic half-circle model you may be thinking of – instead we will use a human arm and a common classroom ruler to measure angles! It turns out that if you hold a ruler at arm's length, one centimeter measures an angle of one degree [1].

This activity is also best conducted in the daytime, and can even be done indoors although it works best out in the school yard or playground. After your students learn to use these tools properly, the **Being an Astronomer** section will give them an activity they can use to try their new skills out after dark at home in their own back yards.

Academic Standards

Science and Engineering Practices

- Planning and carrying out investigations.
- Analyzing and interpreting data.
- Using mathematics.

Crosscutting Concepts

- Scale, proportion, and quantity.

Next Generation Science Standards

- Engineering and design (K-5, 6-8, 9-12).

For the Educator

Facts you need to know

1. A small magnetic compass can tell us which way we are pointing; this direction or ***compass bearing*** is also called ***azimuth.*** In this system, north is 0^o, east is 90^o, south is 180^o, and west is 270^o
2. How high something is off the horizon is called ***altitude***. We record this angle between the horizon and any object in degrees and measure it with a simple classroom ruler.
3. By measuring ***altitude*** and ***azimuth*** together, we can precisely locate any object in the sky!
4. Measuring angles is typically done with a protractor. We can make a simple device using two rulers bolted together to reproduce angles and record them accurately, allowing us measure them later in the classroom. This will be very helpful in mapping constellations!

Teaching and Pedagogy

Unlike our previous activities, this one is about learning to use tools to measure things. You may be thinking: 'But I already teach my students how to use a ruler and a protractor to measure things!' This activity is fundamentally different.

With this new activity, students can learn to measure things that are too big, or too far away to measure in any conventional way. Learning how to measure distant things like the Moon, the Sun, and other planets and stars is a problem that astronomers have been dealing with for many thousands of years – and we are still working on it today!

Once your students have mastered using the compass and ruler to measure altitude and azimuth, students can apply these skills to actually map the position of the Moon in the sky! The important thing with this activity is to make sure the students ***hold the ruler at arm's length.*** Holding the ruler at arm's length insures that the distance between the eye and the ruler is the same every time. If your students do not do this, their results will not be consistent!

Student Outcomes

What will the student discover?

1. Using a magnetic compass and a ruler to measure altitude and azimuth will allow your students to accurately observe and record the position of any object in the sky whether near or far!

2. Using two classroom rulers fastened together, your students will learn to methodically produce accurate maps of any constellation in the sky, reproducing size and shape accurately.
3. Map making is a valuable scientific skill that requires good observing skills and patience! Accurate maps of constellations help us understand the relative size and shape of constellations – even if they are in very different parts of the sky!

What will your students learn about science?

1. Many students confuse ***observing*** with looking. Observing is a useful and practical skill that is essential to the scientist and astronomer. These exercises will help develop this valuable skill in your students, regardless of age.
2. ***Mapping***, recording the position and size of an object relative to the things around it is another way to make a scientific model. In this case, the model is put down on paper instead of being made of objects, but the principle and usefulness is precisely the same!

Conducting the Activity

Materials

1. Small (at least 1-inch, larger 2 or 3-inch sizes will be easier to use) magnetic compass. If your students have smart phones, there are many compass apps available for free.
2. A Ruler marked in ***centimeters***
3. Sidewalk chalk

Building the Altitude-Azimuth Measuring Device

This activity requires no construction – we are simply learning to use a ruler and compass in a new way!

Exploring and Measuring Altitude and Azimuth

1. **[Teacher]** Take sidewalk chalk out to the play yard and mark an X to identify 10 or so places for students to stand while taking measurements. You may also wish to number these spots and write the name of the target next to the X. A simple worksheet which asks students to record the altitude and azimuth and then describe or even draw the object they are measuring is useful.
2. Have the students stand on a fixed place (X marks the spot!) and hold the compass flat and level in their hands. Now turn toward the target (a distant tree or any other object) and adjust the compass so the N lines up with the compass needle; the direction you are looking toward the object shows you the bearing or azimuth direction. Using the compass properly will take some practice. This is often best done in the classroom where everyone can turn to each of the walls and corners of the room and measure azimuth bearings together to be sure everyone is doing this correctly and getting the same results[2].
3. Once everyone has become familiar with the compass and taking azimuth bearings, it is now time to try measuring altitude. Once again, this can be practiced indoors or out. Have students stand on the mark and look toward the object they wish to measure. Hold the ruler at arm's length and count how many centimeters 'tall' the object is. It is sometimes useful for students to work in pairs. One student holds the ruler and sights the object, while the other runs their finger slowly up the ruler. When the finger reaches the top of the object, the observer calls "Stop!" and the measurement is read off the ruler. Record the measurement on the worksheet.

Discussion Questions

1. If everyone measured the same things, why did we get so many different answers? Shouldn't there be ***one correct answer?***
   - **Answer:** The idea that there can be more than one correct answer can be disconcerting to some! In this case, apart from natural errors in measurement, some children have shorter or longer arms, some may not have stood in exactly the same place when they took their measurements. For nearby objects like buildings and flagpoles, the errors can be significant! Remind the students that this activity is about learning to use tools correctly, not necessarily about getting the right answers!
2. If everyone measures a building or a flagpole so differently, how can we expect to measure the Moon and get a good answer?
   - **Answer:** When we measure things that are nearby such as a building or a streetlight, they are so close to us that moving our position just a little can cause a big change in the measurement. When we measure very distant things like the Moon however, it is so far away that the little distance between one person and another – even across town – will make no change in our measurement.

Supplemental Materials

Going Deeper:

Altitude-Azimuth is only one way of measuring the sky. This measuring system is centered on the point where the student stands. If two students were measuring the altitude and azimuth of Mars in the night sky, their measurements would depend not only on where they were standing, but the exact time when the measurements were taken.

The other principal measurement system for astronomers is called the Right Ascension – Declination system, or RA-Dec. This system borrows from the latitude-longitude system we use to measure our position on the Earth. Unlike the Altitude-Azimuth system, the RA-Dec system does not depend upon the observer at all.

See if you can find a map of the night sky using the RA-Dec system. What similarities do you see between this and the latitude-longitude system we use on Earth? What advantages would this system have for astronomers?

Being an Astronomer:

Now that your students have learned to measure altitude and azimuth, let's apply these skills to measure and plot the path of the Moon! There are two ways to do this, the one-nighter activity that measures the Moon's path through the sky over a single evening; and the multi-night activity that measures the Moon's orbital motion over several days. Let's look at each activity separately.

Being a Scientist:

Many coordinate systems have something in common – they can use the Pythagorean Theorem to determine distances. Take a look at a star map with lines of right ascension and declination on it. Each hour of right ascension = 15 degrees.

Find two stars or constellations and measure the distance between them in both the right ascension direction and the declination direction. Treat these measurements like two sides of a triangle and use Pythagoras' equation to find the distance.

$$\text{Distance} = \text{RA}^2 + \text{Dec}^2$$

Following Up:

Ancient cultures used many different ways to measure and mark the positions of objects in the sky. Pyramids, henges, and Sun-circles are just a few. See if you can find out how the Pyramids of Giza in Egypt or the Stonehenge in England were used for astronomy.
