Storytelling with Uniview #15
Learning About the Seasons, Part I

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Understanding what causes the seasons on Earth is one of the more difficult topics in basic astronomy.[1] As a primer on the difficulty that both adults and children have, I recommend watching the short (20 minute) video *A Private Universe* before proceeding with the rest of this article. The video begins with interviews of professors and graduating students at commencement at Harvard, showing that they all share a common misconception about what causes the seasons. The video then focuses its attention on high school students, who have similar unscientific ideas about seasons and phases of the Moon. Despite dedicated instruction, the students are unable to completely shake off their naïve beliefs.

www.learner.org/resources/series28.html

I encourage your entire team to watch this video even if not everyone uses Uniview. It is a wonderful way to start discussions about the difficulties of science education, especially for astronomy, whose phenomenology tends to be removed from people's everyday experiences. It shows how "basic" concepts that we—as experts on the topic—may think of as "introductory," but which are not the case for novice learners.

Why are the seasons difficult to learn? Part of the reason has to do with the complexity of the topic, and the number of sub-topics that have to be understood, before one can gain understanding of the whole. Let's go through a list of these.

At the simplest level, you have to know that the Sun warms the land, air, and water. This may be

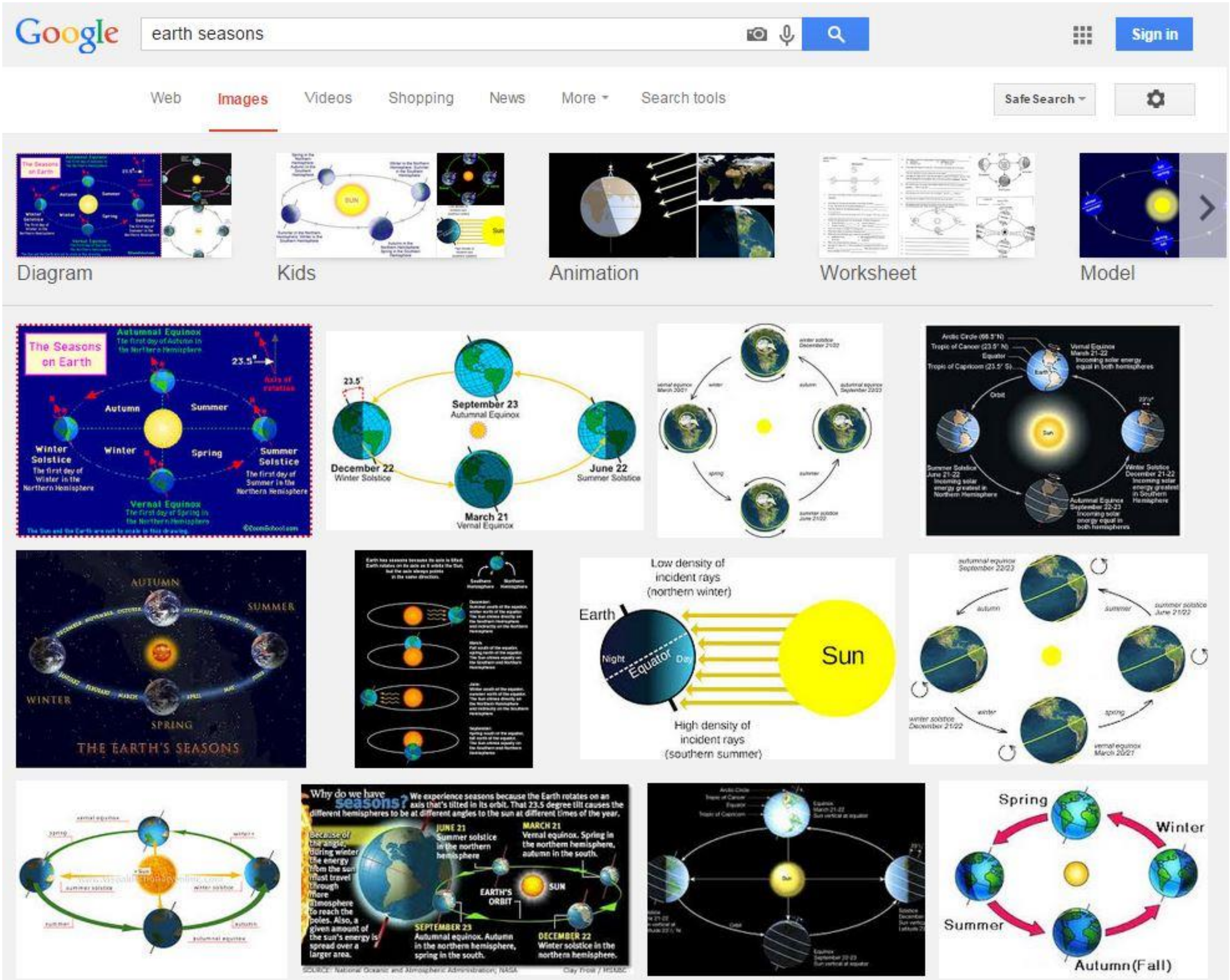
[1] Perhaps most difficult is understanding phases of the Moon, but that is a topic for another time.

obvious to you and me, but our youngest visitors are only just beginning to be aware of basic concepts like these. Other local observable environmental effects include the fact that the temperature and amount of rain (or snow) varies over the course of a year, but on average, they are roughly the same at the same month each year. This basic concept leads to the idea that the seasons are a regular annual phenomena dealing with typical temperatures (and weather) associated with a time of year. Understanding these observed environmental effects are important because they lead to the idea that the temperature of a location depends on the intensity and duration of sunlight striking it, and this can vary by time of year and location on Earth. (Many young learners will think of more immediate proximate causes, such as snow or wind causing the cold in winter.) If you want to go into even more detail, you would note that local geographic effects can also be important (e.g., are we near the ocean?). And there are always day-to-day variations in the weather that can push a particular temperature far past the norm for that time of the year (e.g., a sudden hot or cold spell).

The next important concept is that Earth is spherical in shape (and from *Storytelling with Uniview #03*, there is evidence that young children can have problems understanding this idea), and that we live on that ball (note the problems of understanding gravity from *Storytelling with Uniview #04*). Earth rotating once every 24 hours leads to the experience of the day-night cycle on the surface, and in the apparent motions of the Sun, Moon, and stars in our sky, which appear to circle us throughout the day and night. Furthermore, Earth's axis is tilted with respect to its orbital plane. This tilt is constant in the sense that Earth's north pole is always pointed in the same direction in the sky (near Polaris, the Pole Star), no matter where it is in its orbit. And don't forget that Earth moves in a near-circular orbit around the Sun that takes one year. (The slight orbital eccentricity results in Earth being closest to the Sun in the first week of January, and furthest away in the first week of July.) The relative tilt leads to varying amounts of daylight and nighttime for a particular location on Earth, which depends on where Earth is in its orbit. This also translates into a variation in how high the Sun appears in the sky at different times of the year. In Denver (at a latitude of 40° North), it is highest in altitude at noon during the late June solstice, and lowest at noon during the next solstice in late December. In Denver, at no point does the Sun ever reach zenith, the point directly overhead. Not only does the maximum altitude of the Sun vary over the course of a year, but the length of day does also, as well as the arc that it makes as it traverses the sky, and where the Sun rises and sets (it rises exactly east and sets exactly west only twice a year from Denver). The tilt of Earth's axis also leads to latitudinal effects: the seasons are more pronounced at higher latitudes, and are less so near the equator.

We can summarize these effects into a general descriptive guideline for the different seasons experienced in Denver. In the summer, the Sun rises high up in the sky; it is up for longer (because of the longer day); the intensity of the sunlight is stronger for a given area of the ground that it strikes (often described as "direct" sunlight in textbooks); and shadows are shorter. In the winter, the Sun rises lower in the sky; it is up for a shorter period of time; the intensity of sunlight is weaker because of the low angle of the Sun, so that a given area of ground receives less illumination than during the summer (often described as "indirect" sunlight); and shadows are longer, which result in more opportunities for objects to be shaded from the Sun's light and warmth.

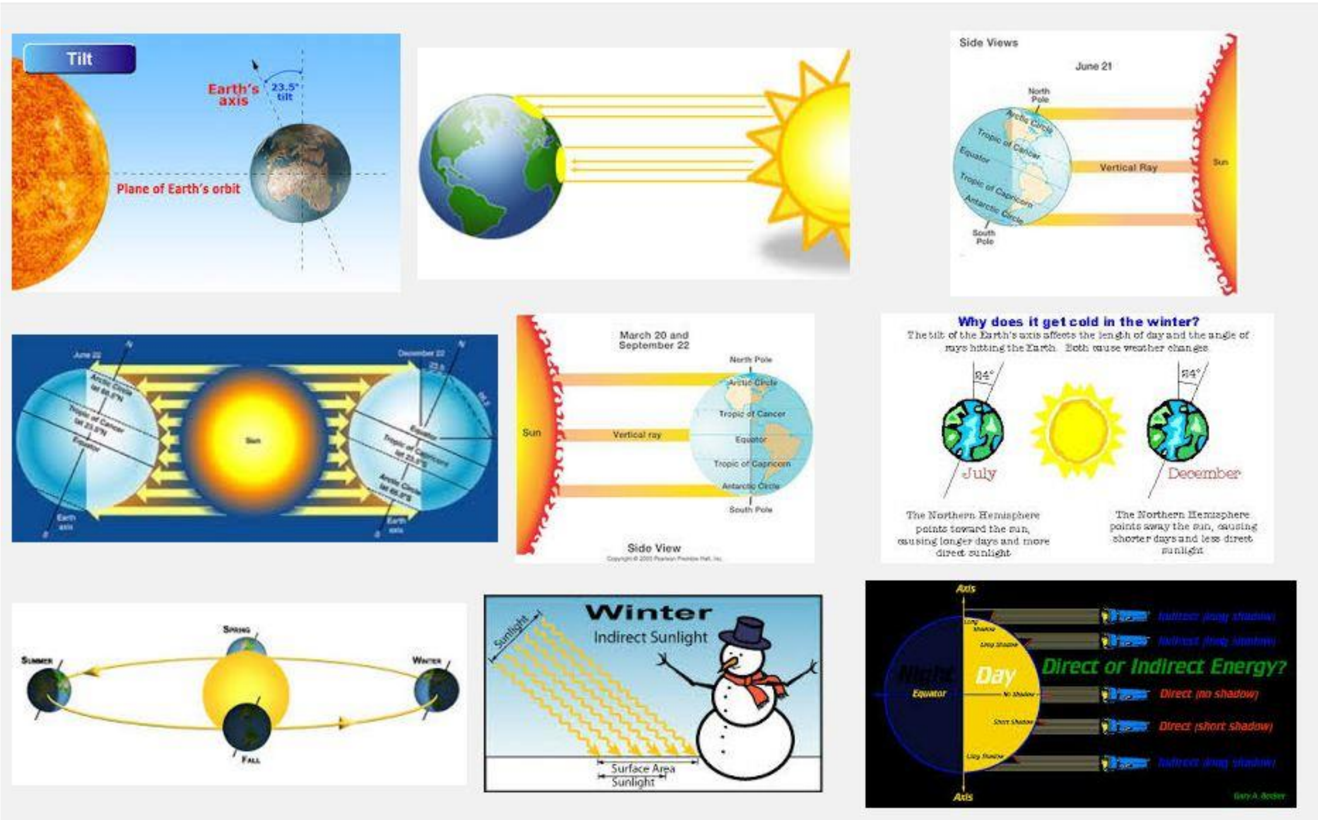
The preceding paragraphs are a rough "learning progression" for the seasons, an ordered list of concepts that have to be understood for a complete comprehension of the topic. However we have not addressed the misconceptions that someone with no expertise in astronomy may have about the seasons. We have covered the ideas of misconceptions in past *Storytelling with Uniview* columns. For instance in *#05* on Kepler's Laws of Planetary Motion, we learn that the public has a tendency to think that planet orbits are much more elliptical or flattened than they really are. This belief may have to do with the common views of Earth in orbit around the Sun. If you do a search for "Earth seasons" on Google's Image Search, you will find the following results to be typical:



In most of these images, we see a lateral view of Earth and the Sun, ostensibly so that Earth can be seen at multiple points in its orbit, along with the effect of the tilted axis on the distribution of sunlight across the northern and southern hemispheres. However this view may lead to the incorrect concept that Earth's orbit is a highly eccentric (stretched out) ellipse, and Earth is much closer to the Sun at certain points in its orbit than at others. Do a search for "Solar System," "planets orbiting Sun," or other like phrases and you will see similar results returned. Only in a minority of the images do you see a "top-down" view of (near) circular planetary orbits around the Sun. Such depictions of planetary orbits may explain why Earth's distance to the Sun is the most common answer given by the general public when asked "What causes seasons on Earth?"

But even when someone is given proper instruction, understanding is often not immediate. Alternative conceptions that are at odds with accepted scientific thinking may be lodged so tightly in someone's head, that when presented with new information, the incorrect notions are not discarded, but only modified. A person's mental model can therefore evolve with time to be a synthesis of both correct and incorrect information. In *A Private Universe*, a student learns about Earth's orbit, and discards her earlier erroneous depiction of its shape upon further questioning by the filmmakers. But she still has a mixed up understanding about what "direct" and "indirect" sunlight means, and this leads to a very perplexed description of the seasons.

Confusion about "direct" and "indirect" sunlight is one example where the formal instruction can lead to new alternative conceptions. Others can come about from traditional textbook diagrams. For instance, a Google Images search of the phrase "tilt of Earth and direct and indirect sunlight" will return pictures similar to those found in many astronomy textbooks about the incident angle of sunlight at different latitudes on the surface of Earth:



However research has shown (Ojala 1992, 1997) that students seeing such pictures can come away with unexpected new misconceptions that include: the equatorial regions on Earth are significantly closer to the Sun than the polar regions; the Earth's inclination relative to the ecliptic causes each hemisphere to tilt substantially closer to or further from the Sun during summer or winter; and the Earth and Sun are much closer in size than they really are. By trying to teach comprehension in one subject, we have inadvertently added new erroneous ideas in other topics!

In the next columns, we will look at what can be done to address naïve ideas about the seasons, and how to use Uniview to teach seasons from Earth- and space-based perspectives.

References

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