Early education opportunities in metoritics

Chris Peterson[1,2]

[1]**Denver Museum of Nature and Science, Denver, Colorado, USA**
clp@alumni.caltech.edu

[2]**Cloudbait Observatory, Guffey, Colorado USA**

Cloudbait Observatory and the Denver Museum of Nature and Science have been operating an allsky camera network in Colorado since 2001. Most of the cameras are hosted at middle schools (ages 12-14) and high schools (ages 15-18), with some notable exceptions targeting even younger students. In addition to generating a rich collection of scientific data, this program has been very successful at introducing students to "real science", where relevant data is collected and analyzed, and the opportunity for new discovery and even publication is present. I will discuss our experience with exploring meteoritics with pre-college age students and the value to both our science program and to early science education.

1 Introduction

The Colorado Allsky Camera Network was established in 2001 by the Denver Museum of Nature and Science (Peterson, 2010). The Museum has a long history of investigating fireball reports and searching for Colorado meteorites. The availability of low-cost video cameras motivated a shift from visual to instrumental analysis, and was also recognized as an educational opportunity, in line with the primary charter of the Museum. Nearly all of the network cameras were installed in schools, and curriculum was developed around their use.

2 Focus

In recent years, STEM (**S**cience, **T**echnology, **E**ngineering, **M**athematics) has become a central focus of educational systems in most developed countries. Experiential learning, inquiry-based instruction, and problem-based learning are all techniques that have been shown especially effective for STEM subjects (Kolb, 1984; Gilmore, 2013). These methods all involve presenting the student with real-world problems which are solved by hands-on approaches, often student designed as well.

Meteoritics represents a powerful educational tool for STEM education. It is inherently interesting to nearly all young people, and can have all the STEM disciplines applied to its understanding.

Here I discuss different curricular ideas we have developed over more than ten years for teaching science and other STEM subjects using a meteor camera network and meteor science as primary tools.

Most cameras in the Colorado Allsky Network are located at high schools, with students ages 15-18. Several are also located in middle schools (ages 12-14) and primary schools (ages 5-11).

3 Curriculum Examples

Triangulation

Because the primary principle in analyzing meteors involves triangulation, this is a good place to start, and a practical introduction to a topic that is either left untreated by conventional math programs, or is only treated abstractly. With younger students, we place a group in a circle with two or more blindfolded, and place a coin on the ground somewhere inside the circle. The teacher then utilizes a mechanical clicker at the coin, and the blindfolded students all point to the sound. The teacher exits the circle, the students have their blindfolds removed, and then identify the intersection of their pointing, allowing them to quickly find the coin.

Figure 1 – Triangulation exercise.

Maps and Directions

Because the primary output from each camera for a meteor event is a pair of altitudes and azimuths representing the beginning and end points, it is natural for students to plot lines on maps (reinforcing triangulation for multiple station events). With primary school students, this may not only represent one of their first practical exposures to maps, but also an opportunity to introduce the idea of angles and using tools such as protractors. Middle school curriculum is similar, but is more likely to utilize technology in the form of mapping software. High school curriculum extends the mapping to three dimensions- using tools such as Google Earth to determine the 3D meteor path and not simply the ground track.

Where potential local falls are identified, ground searches utilizing topographical maps also prove educational.

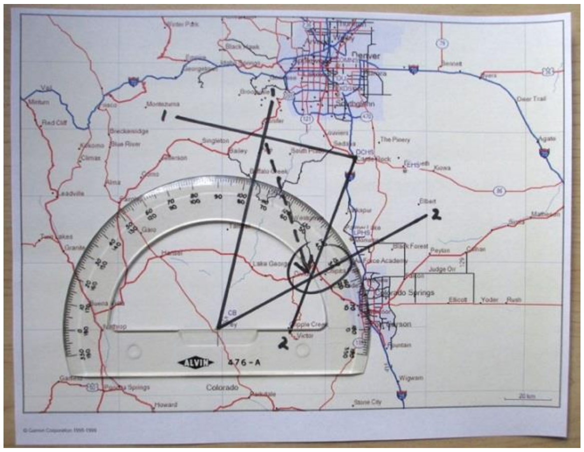

Figure 2 – Mapping exercise.

Statistics

Statistics is usually not addressed seriously until high school. We've found that meteoritics offers an opportunity to introduce statistical concepts much earlier. Students as early as primary school are offered multiple years of meteor data, working in groups to bin events by date. They then plot large histograms on fan-fold paper. This is a labor intensive process, typically requiring several hours. The result is a chart that immediately allows them to identify major periodic showers (periodicity being an important concept itself). We then demonstrate how a spreadsheet program can be used to import data and plot a similar histogram in just a few minutes. In many cases, this is the first time students have ever used this technological tool for any non-trivial purpose. The difference in effort between manual and automated data analysis is apparent to even the youngest students.

Other important statistical analyses are possible with just the basic data from a single station. What is the average speed of a meteor? How does the frequency change with time of night? In a shower, what is the brightness distribution? Students are encouraged to develop questions that can be addressed using statistical techniques applied to a rich dataset.

Light Production

Meteoroids are introduced as bodies that produce light because of material heating. The mechanisms of heating are readily explored with simple experiments such as generating heat by inflating tires with hand pumps. Both black body radiation and narrowband emission are explored in the lab. These concepts, not usually introduced before high school, are readily accessible to much younger students when presented in the context of meteors- exciting events that most of the students have personally witnessed. Of course, all students have a degree of fascination with the idea of heating something until it glows, or of burning chemicals and producing different colors.

Comets and Asteroids

The subject of comets, asteroids, and space dust is generally not presented to pre-university students except in the most cursory way, typically just identifying the terms. These concepts become highly relevant to students working with meteor cameras and live data, however. Recording meteors inspires a natural curiosity about the bodies responsible for these streaks on their cameras. We have developed curriculum around the formation and evolution of asteroids (such as an egg model of differentiation), comets (comet modeling with water, dry ice, dirt, and gravel), comet observation from SOHO data, and visible dust by field observations of zodiacal light (for schools in or near dark locations).

Meteorites

Closely related to understanding asteroids is the study of meteorites. The Denver Museum of Nature and Science is fortunate to curate an extensive meteorite collection, which it has opened up to students who participate in the Allsky program. Working with meteor data adds context to actually handling and analyzing meteorite samples. In addition, discussion of meteorite mineralogy provides an excellent entry into geology.

We also explore impacts–structures such as Meteor Crater in Arizona, and documented events such as Tunguska and Chelyabinsk. Activities for younger students include using topographical maps to create scale models of Meteor Crater; older students explore impact science by dropping or launching small bodies into various media and seeking to explain the nature of the pits created.

Technology

The engineering component of STEM is often the most neglected, as it can be difficult to integrate with conventional curricula. Operating a meteor camera necessarily involves working with an assortment of hardware (cameras, digitizers, computers), solving engineering problems (keeping domes clean, repelling birds, minimizing issues with dew), and working with a variety of software tools (meteor capture and analysis, spreadsheets, GIS).

We have chosen to provide the cameras to participating schools in kit form, requiring the students to understand the design and assemble it on their own. In many cases, especially with younger classes, this is the first time students have ever built anything themselves.

Most recently, we have begun exploring improved camera designs using CAD software and 3D printing. This allows students to develop skills with tools which are frequently not encountered until university or later, and realize their designs with actual components which can be empirically tested.

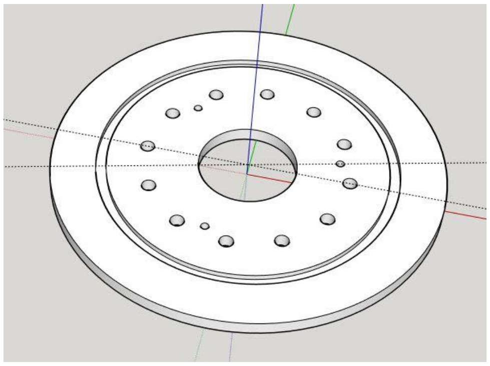

Figure 3 – CAD model of camera component.

Context in Learning

Direct experience with meteor data provides context when students visit collections at museums or academic institutions. While it is common to educate students about the facts of a subject before they encounter it in a setting such as a museum, those facts are typically quite abstract. For students operating cameras, analyzing data, and inferring results, concepts useful in interpreting paleontological, geological, and meteoritic collections are much more immediate. Curators and docents frequently observe that the students that are part of this program ask significantly better and more directed questions.

Presentation Skills

Students are commonly taught non-technical presentation skills (drama, book reports, show-and-tell). Technical presentations are seldom seen or made, however. We include curriculum that involves reading actual scientific papers (a complex skill seldom encountered before university), writing analysis results in the format of a scientific paper, and making oral presentations of those results in the style typically found at scientific conferences.

Collaboration

Students have the opportunity to participate in two types of collaboration: working with students at other schools operating cameras, and working with professional and amateur meteor scientists. Collaboration is a vital part of modern science, but is seldom taught or experienced even at STEM intensive schools. Collaboration is natural and essential for operators of meteor cameras, as the most valuable analyses require input from more than one station. Students may work together in person or by telephone, but most commonly utilize email. I am aware of no other science curriculum programs that offer this degree of student-to-student collaboration.

Figure 4 – Presenting results.

Because meteoritics is also a professional field, the students have opportunities to work with career scientists. This is particularly well suited to meteoritics given that it is naturally a field where professional and amateur scientists work together regularly. Our students have collaborated with scientists at the Museum and at various universities, as well as sharing data with NASA and other institutions. This is very exciting for young students, and builds enthusiasm for science and STEM subjects in general. It also allows students to understand that scientists are “ordinary” people- something that is especially important in a world where they are frequently portrayed by popular media in a very distorted way.

4 Conclusion

We have over ten years of experience incorporating experimental and theoretical meteoritics into early education settings, with students ranging in age from 5 to 18. This has supported an experiential approach to all the STEM components- science, technology, engineering, and mathematics. It has not only made these subjects more accessible than more traditional curricula, but has allowed for the natural introduction of complex concepts at a much earlier age than is common, and has fostered an early excitement about science and science related disciplines. Modern tools make the creation and operation of a small meteor camera network relatively simple and inexpensive.

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