Using Robotic Telescopes to Teach STEM Skills: Undergraduate and High School Students

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ABSTRACT

Since 2004 the NASA Education and Public Outreach Group at Sonoma State University has run a small robotic telescope to be used for teaching at the undergraduate and high school levels. The telescope is part of the E/PO efforts of NASA's Fermi Gamma-ray Space Telescope. The telescope is generally run via a queue observing system as part of the PROMPT/Skynet system run by the University of North Carolina. SSU E/PO Group members train high school teachers and their students how to use the queue to request observations, how to retrieve their data and how to work with the images. Fundamentals of CCD imaging and data processing are taught, as are concepts basic to making scientific measurements, such as statistical and systematic errors, signal to noise and confidence in results. The telescope has been used in classrooms in high schools and small colleges and universities across the United States. We will describe some of the ways students have been able to access the telescope for their observing projects as well as innovative use of observations in general introductory astronomy classes. We will also describe some of the hurdles that must be overcome if the use of remote observatories is to become more widespread, especially at the high school level.

Keywords: Education, STEM, Telescopes in Education

1. INTRODUCTION: THE GLOBAL TELESCOPE NETWORK

The Global Telescope Network (GTN) is part of the public outreach and educational program of NASA's Fermi Gamma-Ray Space Telescope. The network is a group of observatories run by small colleges and amateur astronomers who have agreed to support the science missions of Fermi and its sister missions at NASA and ESA, Swift and XMM-Newton. At present there are approximately 34 members of the GTN.

GTN members often do ground-based followup of gamma-ray burst events, but the bulk of their Network contributions typically involve monitoring AGN as part of a long-term campaign on approximately two dozen blazars. In addition to this routine monitoring, many GTN members also participate in focused multi-wavelength observing campaigns on particular objects. In the past these have consisted of coordinated data gathering from radio up through VHE gamma-ray from Cerenkov telescopes.

The NASA E/PO Group at Sonoma State University operates a small observatory housing a Celestron 14 inch telescope on a Paramount ME. The telescope, called the GLAST Optical Robotic Telescope (GORT), and observatory are typically run remotely and in fully-robotic mode. This observatory is available to students at SSU and other small colleges, as well as to high school students around the US. GORT has been in operation since mid 2004.

2. WHO USES THE NETWORK?

The interface used by most observers on GORT is called Skynet and is operated by the University of North Carolina as part of their PROMPT program. Using Skynet allows SSU observers to request time on GORT and other telescopes connected to the system. Telescopes are located in other parts of the US and the world, including the southern hemisphere. In addition, members at other member institutions are able to request time on GORT. In this way it is possible for group members to chose from several telescopes at different locations and with different filters, cameras and telescope apertures. It should be kept in mind that the Skynet system

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and the GTN are separate. GORT is affiliated with both, but the programs are distinct, with different goals and generally different observers. Specifically, Skynet allows for the robotic operation of GORT and other telescopes.

The remainder of this section will describe some of the observers who are affiliated with the SSU E/PO Group and who gain telescope access through that affiliation. These observers often use GORT for their observations, but they are also able to gain access to other telescopes through Skynet.

2.1 Use of the Network in Colleges

There are several colleges that use GORT on a regular basis. Of course, Sonoma State is one of them, and SSU students use the telescope in several ways. GORT is used to obtain observations for an observing class administered in the Physics/Astronomy Department for junior and senior undergraduates (SSU has no graduate programs in physics or astronomy). In addition, there generally one or two students each year who choose astronomy for their "Capstone" Project, a requirement of the University for graduating seniors. The observing projects undertaken by SSU students are representative of the types of science that can be done using small aperture telescopes equipped with CCD imaging cameras. The projects are focused on photometry, and the target objects are usually variable stars, AGN or transiting planet systems.

Other colleges that use the telescope regularly are Chicago State University and Portland State University. Just as at SSU, Chicago State students use the telescope for their observing class, and the targets are usually of the type already mentioned. However, CSU students routinely make observations as part of their introductory astronomy course for non-majors. The objects observed in this case are far more diverse and include planets, galaxies and various nebulae. The idea here is to use telescopic observations as a motivational tool. They help to engage the students in astronomy and serve as a tangible connection to a particular astronomical object on which they will complete a deeper, book-based, research project. Perhaps of more import, about 40% of introductory science students say that they plan to pursue teaching as a career (Lawrenz et al., 2005[1]). Of these, approximately 250,000 are in astronomy courses (Fraknoi, 2002[2]). Providing more engaging course experiences for these students promises not only to enhance their experience and their understanding of scientific subjects, but it will presumably improve the experience of their students once they are in charge of their own classrooms.

Students at Portland State also use telescopes in the intro non-major class, as well as in the classes that are run for majors. In addition, the instructor at Portland State is developing an idea that is of particular interest: make telescopic observations part of the training for physics majors who are pre-service science teachers. Many science teachers have at best a passing acquaintance with astronomy, and with making real scientific measurements, for that matter. The effort at Portland State could be a model to change that. We will be working with this instructor to help make that happen.

Instructors at both Chicago State and Portland State find that telescopic observations are a powerful way to motivate students by giving them a feeling of "ownership" for the objects that they observe. Since light pollution and weather make observations from Chicago and Portland difficult, having access to a set of remote telescopes in dark areas is vital for these types of classroom assignments.

2.2 Use of the Network in High Schools

Astronomical observing projects are difficult in the high school setting. Many projects are of a duration that does not lend itself to the time frame available in the typical several-week unit in a high school course. What's more, poor weather and hardware failures can stretch an observing program out even more. These limitations notwithstanding, there are two high schools that make regular use of GORT and some of the other telescopes on the network.

Dear Valley High School in Antioch, California has been using the telescope almost since it came online. Dear Valley is one of the relatively few high schools in the US that offers astronomy courses as part of its regular curriculum. Students in these classes must perform some sort of observational project, and many choose to use the remote telescopes for this. In addition, we have had several students from Dear Valley use the telescopes for independent projects and science fair entries. As with the college students, most of the observing projects involve photometric studies of some sort. However, students have also used our telescopes to measure the positions of the

Jovian moons and deduce the mass of Jupiter that way, which seems an excellent way to connect real observations to what are generally just textbook exercises.

The other high school that uses the telescopes as part of its normal curriculum is Ridgewood High School in Norridge, IL. As at Deer Valley, the telescopes are used in an astronomy course as part of the regular curriculum. These students generally observe variable stars.

Another regular program that we run for high school students is a ten week summer internship for high school students from Sonoma County. This program is jointly sponsored by the Sonoma State School of Science and Technology (SST) and the Sonoma County Office of Education. The program, in it's third year in 2011, pairs high school students with SSU faculty from departments within the SST (Biology, Chemistry, Computer Science, Engineering, Geology, Mathematics, Nursing, and Physics/Astronomy). Eligible high school students are all in the summer between their junior and senior years when they do their internship. As juniors the students must be recomended by their teachers and write a short essay on why they would like to work on a science project at the University. They must state how working as an intern relates to their interests and educational goals. Selection to the program is quite competitive. Interns are paid a modest stipend for their ten weeks of work.

The NASA EPO Group has sponsored two students for each of the first two years of internships. The students have learned to make observations using GORT and to reduce and analyze the data acquired. Both students during each summer completed projects involving AGN monitoring. See the poster writeup in this same proceedings for more information on the summer internship program.

3. BARRIERS TO MORE WIDESPREAD USE

The schools mentioned in the previous section are not the only users of our telescope. There are many additional users who submit jobs over Skynet, but the SSU E/PO Group does not work directly with them and we have no direct knowledge of who they are or what they do with their data. But even with these extra unknown users, the network capacity is not even close to being saturated. We could provide observing opportunities for many more classes than we do. So the question arises, why is this resource not being used to its full potential?

We have had discussions with dozens of high school science teachers at regional science meetings about using our telescope with their students. These discussions are lively, and teachers are often excited by the prospect of using the telescope. Nonetheless, most do not follow up with us. There are several likely reasons that could account for this, and we mention them below.

3.1 Standards and Testing

High school teachers in the United States are generally required to follow a curriculum that is aligned with state teaching standards, or sometimes the national standards in states lacking state-developed standards of their own. The standards vary somewhat among the 50 states, but typically include extra-solar system topics only at the high school level. For instance, the National Science Teaching Standards are an example of this (NRC, 1996[3]). Earlier grades are focused on motions of objects in the sky, the planets, and Earth as a planet. Topics like the nature of the stars, galaxies and the origin of the Universe are reserved for grades 9-12. Since these latter topics lend themselves much more to telescopic observations, we might expect that there would be an interest among high school teachers to explore a few of them using telescopes. Yet we have little success convincing the teachers to do this.

One reason is likely testing. Pressure has increased on teachers over the last decade to prepare their students for batteries of standardized tests. The tests do not usually include much astronomical content, nor are the skills gained doing astronomical observations likely to be of any help to test takers. Since teachers promotions and job security are increasingly based on student test results, it is not surprising that they are unwilling to expend effort toward activities that show little promise of raising their students' success rate on the tests.

3.2 Teacher Preparation

Many high school science teachers do not have a strong background in astronomical science. The reasons for this are easy to understand. According to Mulvey and Nicholson, 2007,[4] fewer than 0.2% of the ASTRO 101 students in four-year colleges graduate with a bachelor's in astronomy, and fewer than 0.4% receive a bachelor's in physics. Given the large numbers of students in introductory science courses (presumably including astronomy courses) that do end up becoming teachers, it is clear that most of these teachers do not have degrees in either physics or astronomy. And though they might have taken an introductory level astronomy course in college, such courses are surveys and do not impart a deep understanding of the science of astronomy. Second, and more to the point, survey courses almost never include an observational component. So at best we should expect teachers to have had a poor preparation in making astronomical observations, and they are likely to have had no preparation at all. Even teachers who do have a strong physics background often have not had any experience with astronomy or astronomical observations. Gaining such experience depends on personal interest and the choice of electives in their own education.

Given their backgrounds, almost all teachers will have to put a good deal of extra time getting themselves up to speed with astronomy before they will feel comfortable teaching it to their classes. Even with the help of mentors from the EPO field, putting telescopes into the high school science experience will put a burden on teachers that most are not able to bear.

3.3 Access to Computer Resources

Observing with a remote telescope is a computer intensive experience. Submitting and retrieving the observations themselves requires nothing more than a web browser, but for some schools even this can be an insurmountable hurdle. Firewall settings can block access to outside websites, including those used to run telescopes. Some administrators are unwilling to make exceptions to these access restrictions, making it impossible to use remote observatories at their schools.

Assuming that considerations of network access do not pose a problem, there are other technical issues that have to be addressed. Even with data in-hand, it is still necessary to use some fairly sophisticated software to reduce and analyse astronomical images. The software has two obvious problems: packages that are easy to learn and use tend to cost a lot of money. Schools cannot afford them. There are several free packages, but installing, maintaining and learning them is notoriously difficult. Do we really expect high school teachers to maintain an IRAF distribution for their students, and do we expect the students, let alone the teachers, to learn IRAF?

But even notwithstanding the availability of data reduction software, many high schools, even in relativity well-off districts, lack modern computers in large enough numbers to allow for each student to have a work station. This is changing slowly in some places, but for most schools we cannot expect classrooms to have many computers in them. Sometimes there is a computer lab on campus, but access to those computers is not always easy or convenient.

4. SUMMARY

The availability of fast Internet connections and inexpensive computers, detectors and telescopes has produced unprecedented opportunities for the inclusion of astronomical imaging in science classes. It is now possible for students anywhere in the world to submit observing requests to widely dispersed telescopes around the world and to retrieve those images over the Internet, usually the very next day. However, adoption of this capability has been slow. There are probably several reasons for this.

First, at the college level, there is likely a lack of awareness among instructors that these types of systems exist and are widely available. Unlike for high school teachers, there are no large annual meetings, nor a centralized infrastructure to provide wide dissemination of information about new teaching tools. This is changing somewhat with the advent of communities like the astrolrner email list. In addition, college courses are often very large, especially the introductory classes that are the only astronomy experiences most college students (and pre-service teachers) will have, assuming they take astronomy at all. Managing observing projects in a class of 200 students is probably a logistical problem that a lot of college instructors are not willing to tackle. Finally, many colleges

have campus observatories of their own, and these can be used by undergraduates in observing classes or for independent study. In those cases there might not be a dire need to use a telescope in a remote area.

High schools are a different matter. Most of them do not have access to a telescope. At the same time, astronomy is not usually an integral part of the high school science curriculum. In the high schools that do use our telescopes, astronomy classes are integral to the curriculum, in both cases because the teachers have a strong personal interest in the subject. But even when astronomy is something that teachers would like to offer, their lack of background in astronomy can be a huge barrier to them doing so, as can a shortage of decent computer resources and an over-emphasis on standardized testing to set the curriculum.

Perhaps programs like the one contemplated at Portland State are a way out of this. If pre-service teachers who are science majors get more realistic science experiences, like observational projects on a remote telescope for example, it could in time improve the skills of science teachers around the country and make them better prepared to use innovative and authentic science lessons in their classrooms.

I'll give the Portland State professor who is developing this idea the last word:

> Your willingness...to let my astronomy students use a real research telescope for two observations was a key element for transforming the class from a straight lecture format to a student-centered, lab-focused experience. The majority of the students I teach are math-phobic but excited to learn about the cosmos.
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> -Jack C. Straton
> Associate Professor of Physics
> Portland State University

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