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Robotic telescope labs for survey-level undergraduates

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For the past dozen years, the University of North Carolina (UNC) at Chapel Hill has been developing a unique, survey-level astronomy curriculum, primarily for undergraduate students, with the goal of significantly boosting STEM enrollments on a national scale, as well as boosting students' technical and research skills. Called "Our Place In Space!" (OPIS!), this curriculum leverages Skynet—a global network of ≈20 fully automated, or robotic, professional-grade telescopes located at some of the world's best observing sites. We have recently received $1.85M from NSF's IUSE program to expand OPIS! nationwide and $3M from DoD's NDEP program to integrate a global network of 5-m to 30-m diameter radio telescopes into Skynet, and to develop a follow-up curriculum to OPIS!, called "Astrophotography of the Multi-Wavelength Universe!" or MWU! Both grants come with funding for participating instructors.

Fig. 1. Left: Three of the six original 16-in diameter Skynet telescopes at Cerro Tololo Inter-American Observatory (CTIO) in Chile. Center: One of the three upgraded 24-in diameter telescopes at CTIO (displaced originals have been relocated to other dark sites around the world). Right: Skynet's 20-m diameter radio telescope at Green Bank Observatory in West Virginia.

The Skynet Robotic Telescope Network is one of the largest in the world (although not the only one! The Las Cumbres Observatory Global Telescope,[1] to give another example, also has opportunities for instructors and students). Funded primarily by NSF, UNC-Chapel Hill began building Skynet in 2004. The heart of Skynet is sophisticated telescope control and queue scheduling software that we developed to work with most commercially available telescope hardware. The network now numbers ≈10 UNC-Chapel Hill telescopes, ≈10 telescopes belonging to other institutions, and another ≈10 telescopes are scheduled for integration over the next few years. Some of these telescopes are displayed in Fig. 1. Skynet optical telescopes range in size from 14 in to 40 in and span four continents and five countries. Also, Skynet already includes a 20-m diameter radio telescope. To date, roughly 40,000 students have used Skynet.

OPIS! is a Skynet-based laboratory curriculum for undergraduates in small to very large introductory survey courses.[2] OPIS! consists of eight, and soon nine, labs in which students use the same research instrumentation as professionals to collect their own data. They then use this self-collected data (astronomical images and spectra) to reproduce some of the greatest astronomical discoveries of the past 400 years and gain technical and research skills at the same time. OPIS! is built around the cosmic distance ladder, which serves as an organizing principle in many introductory astronomy courses/sequences, and as such it reinforces students' classroom experiences. The goal of OPIS! is to move beyond laboratory experiences in which students learn how to use a telescope for its own sake, to instead use it to do science—the same science that they are learning in class. Although students are not carrying out cutting-edge research, they are using cutting-edge research instrumentation, and consequently there is great overlap with the Course-based Undergraduate Research Experience (CURE) pathway model.[3] Furthermore, these labs and observing experiences are specifically designed to pair with standard introductory astronomy curricula, facilitating widespread adoption.

MWU! will be for students who have already completed OPIS!, and will be able to provide this smaller group more telescope time per student, making possible color- and radio-mapping, inquiry-based explorations. MWU! will consist of three optical, three radio, and two capstone observing experiences that integrate optical and radio, on the subjects of stars, galaxies, and light-producing mechanisms. Astrophotography will serve as this curriculum's "hook."

The introduction of OPIS! at UNC-Chapel Hill 12 years ago resulted in a >100% increase in enrollment over a five-year period—now one in six UNC-Chapel Hill undergraduates takes at least one of our introductory astronomy courses. It additionally contributed to an ≈300% increase in astronomy-track majors and minors (from ≈10 to ≈40, ≈50% female). OPIS! has since been adopted by ≈two dozen institutions, including large R1 institutions, smaller undergraduate-only institutions, minority-serving institutions, rural-serving institutions, community colleges, and advanced college-preparatory high schools. It is used in a variety of formats: integrated into the classroom, as a separate/stand-alone laboratory experience, and fully online.

Funded by an earlier NSF TUES award, OPIS! was the subject of a preliminary/exploratory study across 10 of these institutions and all of these formats. The study found that once factors such as the grade that each student expected to receive

and their career plans were controlled for, Skynet-based observing experiences were one of only two course components that led to a statistically significant improvement in STEM attitudes (the other was attending lectures).[4] In contrast, traditional telescope and non-telescope labs, as well as in-class activities known to yield learning gains, did not have a similar effect on attitudes. A larger case study, encompassing three times as many institutions, that addresses not only students' attitudes but also self-efficacy and conceptual knowledge in astronomy and STEM is now underway.

A recent addition to the curriculum is 65 overview and tutorial videos, which are embedded in the labs and also available online.[5] They are currently garnering ≈400 views and ≈30 hours viewed per day on YouTube. They can be used in multiple ways. For some instructors, they are helpful supplements that students can consult when completing labs. Others use them as the primary mode of lab instruction, freeing themselves up to focus more time on regular instruction and to work with students one-on-one as needed.

OPIS! works equally well online as in person. Indeed, UNC-Chapel Hill has offered both in-person and online sections of OPIS! every year for the past decade. When the pandemic struck in spring 2020, OPIS! sections at about two dozen institutions were among the few science lab courses at these institutions that were able to transition to fully online without difficulty.

We have partnered with homework-assessment company Cengage/WebAssign, which has packaged the OPIS! labs into an interactive, and maximally auto-graded, online manual/text. Most participating institutions choose this product, both for its ease of use and because it greatly simplifies grading, particularly for large numbers of students. It has an ISBN number and can be ordered by campus bookstores the same as any textbook (allowing students to use financial aid money instead of personal funds), and it now integrates into standard learning management systems (LMSs).

Cengage/WebAssign charges for this product (typically $65/student), but a portion of this cost is returned to UNC-Chapel Hill to support telescope operations and maintenance, software maintenance and further development, etc. This gives OPIS! a long-term sustainability model that has allowed it to survive grant funding cycles. (Currently, Skynet costs ≈$350K/year to operate.) It also gives students unique access to research-grade equipment at some of the best and darkest sites around the world.

Each fall, we offer Zoom training sessions for adopting instructors, where we review one lab per week. We also record these sessions for instructors with time conflicts and for instructors adopting off-semester. Each spring, we offer weekly Zoom sessions for instructors who have already implemented OPIS! at their institution. Here, we review updates to the curriculum and to the supporting software, and we collect detailed feedback so we can continue to improve the labs.

We are still accepting instructors at undergraduate institutions who wish to participate in the NSF IUSE study. Additionally, we are always happy to work with instructors of both undergraduate and advanced high school students who wish to integrate OPIS! into their courses.
For more information, email introastro@unc.edu.

Funded by our NSF IUSE award, we have up to $3500 for each of approximately 40 adopting instructors to learn and implement the curriculum at their institution. This work includes attending one semester of training sessions, one semester of feedback sessions, and administering two pre/post surveys to your students each semester. One survey measures student attitudes, self-efficacy, and career intentions. The other measures content knowledge. The end result will likely be the largest study of the positive impacts of robotic-telescope use in education ever conducted, at least at the undergraduate level.

We gratefully acknowledge support from the NSF's TUES, STEM+C, and IUSE programs (awards 1245383, 1640131, and 2013300, respectively), as well as upcoming support from DoD's NDEP program.

References

1. T. M. Brown et al., "Las Cumbres Observatory Global Telescope Network," *Pub. Astron. Soc. Pacific* **125** (931), 1031–1055 (2013).
2. For additional information about OPIS! and implementing it at your institution, see https://tinyurl.com/opis-workshop, https://tinyurl.com/opis-links, and/or email introastro@unc.edu
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