Authentic Data Inquiry a Focus in STEM Programs

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Student-centered inquiry and data analysis are becoming an increasing focus of K-12 STEM programs. When the Education and Public Outreach portfolio was carried out under the scope of the *Chandra* mission and CXC, working with Dr. Terry Matilsky at Rutgers University, we pioneered a program of authentic data analysis activities using the SAO-developed astronomical imaging and data visualization application, SAOImage DS9 (http://ds9.si.edu), with a virtual observatory. *Chandra* EPO, and later MIT, ran summer workshops for high school students for 10 years using this program. A longitudinal study carried out by Goodman Associates, an independent evaluation organization, gave evidence that the program strengthened student confidence to succeed in STEM subjects, reinforced interest in STEM subjects and STEM majors, and increased skills in problem solving.

Despite its success, the program was discontinued as Congressional and Agency budget decisions decreased EPO budgets. And finally, as this audience knows, the EPO mandate was removed from missions and restructured into the Cooperative Agreement administered through NASA's Science Mission Directorate (SMD) under which these activities operate today. *Chandra* is a participant in NASA's Universe of Learning (UoL) collaborative that includes STScI, IPAC, JPL and Sonoma State University. *Chandra*-specific partners include SAO's Science Education Division, The National Science Olympiad, and the Christa Corrigan McAuliffe Challenger Center at Framingham State University.

Through these transitions, CXC has kept the student-centered data analysis activities alive in various forms which has led to many more manifestations of such programs and activities. This article describes some of the most interesting.

X-ray Data Analysis in Coursera

After more than a decade of teaching the *Chandra*-based Astrophysics Summer Institute as well as an online full semester course in X-ray data analysis through Rutgers, Terry Matilsky has adapted the material for a broader audience. He developed about 30 video lessons and initiated a Massive Open Online Course (MOOC) through Coursera (https://www.coursera.org). This course utilizes SAOImage DS9 to allow sophisticated discussions involving time variability and energy spectra and full immersion for students in *Chandra* observations of objects such as Cas-A, 3C 273, the Bullet Cluster, and Cen X-3. Since 2014, the course has been presented three times via the Coursera platform.

Some relevant statistics. Engaged students exceeded 20,000. (Formal enrollments were higher, but this number represents students that actually accessed the material in some way.) The number of video viewings exceeded 200,000. The total number of students who submitted all (quite challenging) homework assignments and passed with distinction exceeded 1,000.

Much has been made of the low "completion" rates for MOOCS, but it is clear that people use these courses in many ways. A substantial number of students wrote to say how much they enjoyed the material, even though they didn't submit the homework. A regular highlight of the course are the discussion forums, whereby students engage the staff and expand the scope of the data analysis. It is quite gratifying to see spontaneous study groups form, some in foreign languages such as Spanish and Greek. The next session of the course is scheduled to begin on January 23rd, 2017 and will utilize a new Coursera platform that will allow for courses to be run more or less continuously throughout the year.

Collaborative Efforts in the Universe of Learning

As part of the UoL partnership, *Chandra* staff have been collaborating with SAO's MicroObservatory Robotic Telescope team on efforts to create authentic data exploration experiences for a wide variety of astronomy learners. Over 50,000 users per year—including classroom, after-school, museum, and citizen science audiences—currently request and receive astronomical image data from the MicroObservatory telescopes.

Since the suspension of the original data analysis workshops, computer technology developments have enabled progress in connectivity, ease of use, and user-friendly interfaces. The browser-based SAOImage JS9 (http://js9.si.edu) program was developed out of SAOImage DS9 to enable wider audience use of data analysis functions. JS9 was consciously designed with features that make it easy for novice learners to see the quantitative information that is behind the image data, thereby allowing them to pursue a wider variety of authentic inquiry projects than could have been supported in the past.

The MicroObservatory (MO) team from SAO's Science Education Department has been working with Eric Mandel from SAO's High Energy Division to create a modified version of the JS9 interface with features customized for MicroObservatory's novice astronomy learners. He has been supporting the MO project by creating targeted JS9 modules that help bridge the gap for "apprentice" astronomers to enhance and analyze their FITS images using the same powerful tools that *Chandra* scientists use.

As all good collaborations do, this one goes both ways—several features requested by the MicroObservatory team to specifically meet the needs of novice users have become standard features of the production version of JS9. One notable example is the live graphic color table that now ap-

pears below the JS9 image window, giving users a much more intuitive sense of how their adjustments of contrast, bias, and extrema values affect the visualization of the image data. The next effort of the MO team is to seamlessly integrate many of the images from the *Chandra* Open FITS project into the MicroObservatory JS9 interface, so that users can compare their own MicroObservatory telescope data with that of NASA's multi-wavelength space observatories.

In a similar, but slightly different direction, the CXC UoL team has developed a "scaffolded" model which consolidates all of the data analysis activities developed through *Chandra* EPO and UoL, including pencil and paper data exercises for low-resourced areas (see "Imaging" at *http://www.chandra.si.edu/edu/formal/index.html*), Open Fits (*http://chandra.harvard.edu/graphics/resources/handouts/lithos/openfits_litho.pdf*) and student coding programs (*http://chandra.harvard.edu/edu/pencilcode/*). A future addition currently under development will be a JS9-based program that will allow student analysis and production of multi-wavelength images.

Our UoL partner, the National Science Olympiad, which reaches over 220,000 students through over 7,500 teams nationwide, also uses the data analysis activities for study materials and in astronomy competitions.

Successful Summer Internship at OCC

Finally, in a different area, the CXC has been hosting undergraduate summer interns funded through NASA's Space Grant Consortium to work at the Operations Control Center (OCC). This past summer, two exceptional interns developed a 3D model of the *Chandra* Observatory that visually represents live thermal telemetry data coming down from the spacecraft. Using engineering blueprints to locate thermistors, intern Amy Nuccitelli developed the model while intern Jonathan Brand developed an imbedded interactive 3D display website. This tool is currently used by OCC planners and engineers. See the *Chandra* blog post (*http://www.chandra.si.edu/blog/node/612*) for more information.

We encourage any of our audience with ideas for inquiry or data analysis activities that can be used with students or the general public, or who want to participate in any of our public programs as a developer, reviewer, or presenter to contact Kathy Lestition at klestition@cfa.harvard.edu. ▪