LSST Formal Education Design

Summary

The goal of the formal education program is to create engaging and authentic astronomy classroom activities and support materials for secondary and undergraduate students in the United States and Chile. The LSST EPO Team will develop relevant science investigations designed to improve critical thinking and evidence-based reasoning, data analysis skills, and complex problem-solving abilities. These online research experiences can be life-changing for many students, and spark a deep, lifelong curiosity about discovery and science, while also improving science literacy and positive attitudes about the role that science plays in society.

Investigations will be developed within six identified central science themes. These themes cover topics that are commonly taught, to encourage broad adoption, while at the same time incorporating the unique aspects of LSST data sets. Each activity will make use of online notebooks with embedded widgets to interact with data in an efficient way so students have more class time to focus on the science. Notebooks may be customized in a number of ways and adjusted to support varying levels of challenge for the learner.

Instructional design will incorporate the three-dimensional teaching and assessment design of the Next Generation Science Standards (NGSS) in the United States and the Curriculum Nacional in Chile. Extensive user testing will serve to inform design considerations for diverse audiences in both countries. All materials will be available in both Spanish and English.

Quality professional development is critical to program success. Instructors will be supported through training workshops, online resources, social media and responsive human contact, both during the launch of the program and throughout Operations. This includes the ability of the EPO Team to be agile and responsive to trends in technology. These collective efforts will foster a community of teacher/trainers that will in turn interact with new users, and who may contribute ideas and activities.

Audience

The intended audience for formal education is instructors in the United States and Chile at the advanced middle school through high school levels, as well as college instructors who teach general education “Astronomy 101” courses. The students in these settings represent a range of ages, but they essentially have the same level of sophistication when it comes to prior knowledge of astronomy. Therefore, our educational activities have been designed without reference to grade level, leaving to the instructor’s discretion how to use, modify and sequence them.

The EPO team is committed to developing materials that will appeal to diverse audiences. To that end, user testing and focus groups will incorporate instructors and students from diverse

communities to inform us of helpful revisions that will improve the quality and accessibility of the finished products.

Beyond this (targeted) audience, it is anticipated that some independent study or home school students will use the notebooks. It is likely that international users, especially those from Spanish-speaking countries, will also adopt and use our activities because materials in that language are not commonly available.

Leaders of informal education may also become a significant user group, though not the intended primary audience. These may be scout or 4H leaders, STEM group or club moderators, science center or park personnel. Some amateur astronomers, such as variable star or asteroid observers, may be keenly interested in using online notebooks to conduct their own explorations.

Online notebooks

All investigations will make use of online notebook technology. Jupyter notebooks are an example of this technology, which are open-sourced web applications that have support for multiple programming languages. Our notebooks will use Python code and will be customizable, so teachers can modify them and save their unique version.

Online notebooks provide a means to access and analyze large data sets without downloading files or installing special software. Because they are accessed through a website, they eliminate many common problems for schools, such as permission, bandwidth and firewall issues. The notebooks are designed for use on any tablet or computer with a modern operating system and internet access. This will allow students to be able to work on assignments and projects outside of class if desired. They may also be used in online classes.

The tools (widgets) contained within the notebooks minimize time spent on common data processing routines such as spreadsheets and graphing, shifting the focus to learning scientific practices and principles. This will enable students to complete investigations within one or two class periods, which is in line with needs of the majority of instructors.

We will incorporate the unique aspects of LSST data in notebook designs. Captivating, wide and deep images can serve as focal points to segue between the common experience of the learner and the science extracted from data analysis. Large data sets mean every student can have a different object to analyze. Extensive time domain studies of objects such as supernova and asteroids will be possible. Co-added images and subsequent annual data releases will reveal new objects to explore.

Instructional Design

The formal education program is designed around six astronomy themes that are aligned with the four pillars of LSST science as well as with the "big ideas" covered in most introductory astronomy courses:

- Properties of Light
- Properties of Stars
- Solar System Objects
- Galaxies and the Milky Way
- Cosmology
- Dynamic Sky (time domain astronomy)

We will develop guided student explorations of LSST data with defined learning outcomes for each science theme listed above. Every online notebook will be accompanied by supporting materials for the teacher in a set we call an *investigation*. Investigations are designed so that extensive preparation and unpacking by the instructor is not necessary. This applies not only to the notebook, but also extends to assessment tools packaged with each investigation. Our goal is to achieve high quality in both the activities and support materials, so most educators will not require extensive training. A teacher should be able to work through an investigation using the provided support materials and find that it is as easy to implement as a new pencil and paper activity.

All investigations are designed to take between one to two hours to complete, depending on how much class discussion and assessment is included. This is an important aspect given that teachers frequently have problems trying to cover all the curriculum in the limited class time they have.

Two to three investigations will be developed for each theme: one *foundational investigation* and one or two *extension investigations*. Foundational investigations explore the most significant learning outcomes of the science theme. They are considered as starting points. Extension investigations offer deeper topic development within the theme, but the content and learning outcomes are not necessarily more challenging.

All investigations include the following components:

- Student notebook: Online notebook with interactive widgets for students to explore data and document what they have learned.
- Teacher notebook: Identical to student notebooks, but contain real-time class management tools, such as “monitor student progress” or “combine class data sets”.
- Teacher guide: Contains information specific to implementing the activity, such as learning outcomes, standards alignment and teacher notes
- Assessment materials: Additional questions and rubrics for assessment, correlated to standards

In addition, foundational investigations, as the starting point of each theme, will have the following components:

- Introductory video
- Assessment video
- Student notebook *with code*

The intent of the introductory video is to inspire and engage students by the use of captivating images or visualizations. Preliminary questions will be posed that tie into the main learning outcomes of the investigation.

The assessment video will serve as an evaluation tool. It will feature students discussing what they have learned through the activity, but some of their explanations contain errors. This offers an opportunity for students to identify the errors and offer corrections. While discussing, students have to back their ideas with evidence and visible thinking. Diversity will be incorporated in the portrayal of student actors and their names. Alternatively, the assessment video may be converted into a pdf. This would give students the opportunity to view the entire dialog and could be used offline.

Since these videos refer to the science theme without referencing the notebook, teachers may elect to use the videos in different contexts if desired.

An alternate version of the student notebook will be available for students interested in coding. This notebook will have the same learning outcomes, but the code will be partially revealed and its functionality explained. Students will be encouraged to manipulate variables within the code using a guided process. An optional challenge problem will be included which will draw upon both science and coding aspects. The intent of this notebook is to provide students with an introduction to understanding coding and its important role in science and engineering, but *not to teach coding.* This notebook will be available only for foundational investigations, not for extension investigations.

By exposing students to more of the process of how notebooks are designed and how widgets interact with data, notebooks with code serve as a bridge to show students how they might move from a prescribed teacher-directed activity to a student-directed exploration of data, where students use the widgets and design their own investigation. The use of these notebooks aligns with EPO's goal of communicating how data science is used to manipulate and interact with large data sets.

Designed for Education Standards

Where possible, the content and teaching style of investigations will incorporate key aspects of the Next-Generation Science Standards (NGSS)[1] in the USA and the Curriculum Nacional[2] developed by the government through the Ministry of Education (MINEDUC) in Chile.

The Next Generation Science Standards were built on a framework established by the National Academy of Sciences and were developed by 26 lead states. They are not connected to the federal government and therefore not subject to administration or congressional mandates. Since their completion in April of 2013, the NGSS has been adopted by 20 states (as of March

[1] http://www.nextgenscience.org/
[2] http://www.curriculumnacional.cl/inicio/

2018) plus the District of Columbia. An additional 19 states have adopted a modified version of NGSS based on the NRC Framework and 40 states in total have indicated interest in adopting them.

NGSS introduces a new way of teaching science, with a focus on practices, cross-cutting scientific principles, and exploring topics in depth as opposed to breadth. Astronomy standards are featured with increasing complexity from elementary through high school. LSST formal education investigations address some standards in both physical science and astronomy and are well-positioned to take advantage of "in depth" approach to learning.

In Chile, the educational standards have undergone a process of revision for all academic levels between elementary and high school. At present time (June 2018) the standards have been approved and are starting to be implemented up to grade 10. These standards focus not just on acquiring knowledge but also on developing skills and attitudes. The new standards specify that astronomy will be taught as a part of physics in grades 9 and 10.

The standards for the last two years of high school are expected to be approved and ready for implementation by 2019. At the moment it is unclear if more astronomy topics will be included.

The university level is focused on specific and practical requirements for certain professions, so the equivalent of an "Astronomy 101" course is not common as in the United States but may exist in some colleges.

The Education Hub

The Education Hub, hosted within the EPO website, functions both as the launch point for the formal education investigations, and the repository for support materials. In addition to the investigation components, tools located on this page will enable searches as well as generate suggestions of possible sequences of investigations.

To support the needs of pre-college instructors, the Education Hub will contain customizable NGSS rubrics for assessment and ideas for integrating NGSS-style teaching techniques.

Tutorial videos and an FAQ for both teachers and students will be available such as how to use or customize an online notebook.

To access all the material, teachers will need to create a password-protected account. Within their account, they will be able to use class management tools to upload rosters, assign groups and challenge levels, and assign investigations in advance of class time.

Account login capability provides a means of recognizing who is using the LSST formal education products. It is also an entry point to join the mailing list. This can inform users of new data releases, new or revised investigations, or upcoming professional development.

Addressing the needs of resource-poor schools

Without Internet-enabled devices, schools cannot use online science notebooks. Our diversity goals include engaging underserved communities that may not have the financial resources to provide enough devices to be able to participate in our programming. Therefore, EPO is planning to purchase tablet devices with the intention of loaning sets of them for short periods to educators that have demonstrated sincere need and strong commitment by participating in our professional development program.

Another alternative for schools who have internet access but limited numbers of computers is to work through a notebook investigation with the class using only the teacher workstation and a projection device. While this does not allow for differentiation or the experience of each student working with a unique data set, most aspects of the investigation, such as using the instructional videos and discussions, and using an online notebook to query and analyze a data set can be accomplished.

Professional Development

To help instructors develop confidence in using online notebook technology and to become familiar with the content and structure of investigations, LSST will design and test professional development options during Construction.

In fiscal year 2018, two groups of experienced educators from both the secondary and college levels were invited to interact with notebook and web page prototypes and to provide feedback on them, as well as other aspects of the formal education plan, from instructional design to support materials. The individuals in these initial groups were carefully selected with a consideration to a role with their future involvement with EPO as potential local-area trainers.

Two local field tests in a Tucson high school and at the University of Arizona in the spring of 2018 were conducted with students testing notebooks. Both of these initiatives helped to inform the design of materials and raise awareness about what aspects of professional development need to be emphasized.

Teacher training of select individuals will begin in fiscal year 2019, to be followed by pilot testing with their students in the US and Chile. Both will help to aid with design refreshes and effective professional development strategies.

Closer to the start of Operations, teacher training workshops will be carried out at professional society meetings and educator conferences and in areas local to Tucson, Arizona and Santiago, Chile. These will provide an extended time for teachers to receive training, interact with the materials, ask questions and develop a level of confidence in using online notebooks. Potential conferences include the American Association of Physics Teachers, the National Science Teachers Association annual and regional conferences, and the American Astronomical Society.

Center for Astronomy Education workshops, NGSS workshops, and AAAS Education workshops are other considerations, with an eye to regional representation.

In Chile, the new public education law establishes ongoing free professional development for all teachers.[3] It is a potential vehicle for training teachers in the use of LSST investigations. The Chile EPO coordinator will monitor these developments in conjunction with the education team and will make use of opportunities such as this.

Often the teachers who are most invested in learning are those who attend conferences and workshops. But financial constraints severely limit conference attendance for most teachers. Teacher professional society memberships and conference attendance throughout the United States have been declining for years, and that trend is not reversing. Other strategies need to be employed.

Two effective scenarios attract teachers to professional development. The first is mandatory training during the work day. This is happening in the K-12 world as states adopt the NGSS standards. EPO representatives actually could be in demand to present extended multiday workshops, if they are marketed as NGSS astronomy activities. Another option, and the most realistic for a majority of educators, is online training.

Online training can be very effective when it is a blended learning experience, where part is guided and part is independent. It can also be done at the convenience of each individual. A catalog of previously-recorded professional development web seminars will be available as well.

LSST-EPO will adopt the model of training regional resource teachers, successfully employed by programs such as Project Astro[4], RBSE[5], SPICA[6], and the JPL Solar System Ambassadors.[7] A cadre of vetted teachers are recruited, trained and sent forth to spread the news and to train others. Some scientists from the LSST Community can be similarly trained. Trainers are recognized over the long term to keep them motivated and to show appreciation but are not financially compensated.

Selection of the first groups of trainers will be critical for the early program success. The most effective trainers are enthusiastic and engaging teachers who are lifelong learners, with proven professional development "track records" that demonstrate follow-through with prior leadership and training experiences. We will work to instill a spirit of "inner circle" program ownership in these first individuals.

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[3] http://www.politicanacionaldocente.cl/
[4] http://www.astrosociety.org/education/k12-educators/project-astro/
[5] http://www.noao.edu/education/arbse
[6] http://www.cfa.harvard.edu/sed/projects/spica.html
[7] http://solarsystem.nasa.gov/ssa/home.cfm

We will first reach out to those teachers who are most eager to learn. An effective way to find such people is to offer local area workshops through trainers and LSST science partners. Most teachers find out about quality activities by communicating with each other, either via social media or word of mouth. The enthusiastic teacher who has successfully used an LSST notebook will do much of the heavy lifting for publicizing the program.

This approach also applies to our commitment to address diversity. In order to reach diverse audiences, we will need to market to organizations that have developed infrastructure to help link us to educators and potential prime locations for teacher training. We need to give thoughtful consideration to which groups we can work with to develop a symbiotic relationship, what their needs are, and how we can help meet them. This approach would affect a broader impact for reaching diverse audiences rather than a scattershot plan of selecting a “diverse” location to host a workshop. Such partners are most likely to found at educator conferences or through organizations whose mission is to "close the achievement gap".

A repository of materials on the Education Hub will complement regional training workshops and online web seminars. Sustained and timely human support will be required for the length of Operations for those who are trying to work through LSST activities remotely. Regional contact information on the Education Hub can connect individuals who are either trainers, instructors who are using LSST investigations, or a scientist who has agreed to help with EPO.

Marketing

Even the best programs are ineffective if people don’t know about them. Marketing is an important first step in attracting others to the Education Hub and professional development opportunities.

A multi-faceted approach will reach the most people. In addition to professional development workshops at conferences and online web seminars, we should aim to publish articles in science education journals. Shorter news releases or links could be featured on the websites and in the newsletters of science education organizations. Social media channels will effectively help to spread awareness of EPO investigations.

If some of the formal education products such as the tutorial or instructional videos are hosted on an active social site such as YouTube, it will enable more people to find us by way of a simple search, and from there work their way back to the LSST website and Education Hub. LSST EPO should also explore popular social media as a means to attracting and supporting users.

Outcomes

The intended outcomes for educators are:

- Increased awareness of LSST and its functionality for educational purposes
- Increased confidence integrating LSST data into lessons

- Increased awareness, knowledge, and skills regarding the use of online science notebooks with their students
- Improved astronomy content knowledge and confidence using online tools through professional development activities

Throughout beta testing during LSST Construction, the formal education program will be evaluated using surveys, focus groups, and EPO Portal analytics to determine the extent to which developed activities support stated outcomes. Enrollment information and feedback on professional development prototypes will be monitored to ensure that a diverse audience is reached and that an increasing number of teachers show interest.