DESIGNING STANDARDS-DRIVEN SPACE SCIENCE EDUCATIONAL OUTREACH FOR FORMAL EDUCATION. M. L. Urquhart[1] [1]Department of Science/Mathematics Education and the William B. Hanson Center for Space Sciences, The University of Texas at Dallas, 800 W. Campbell Road, Richardson, TX, 75080 (urquhart@utdallas.edu)

Introduction: In designing education programs in conjunction with space science research, education/public outreach specialists have long relied on the natural appeal space has for students and the general public. Capturing audiences with engaging topics and activities is insufficient, however, in the context of formal (classroom-based) education. In the ever tightening schedule of today's schools and with high stakes testing mandated under No Child Left Behind, education programs intended for use in formal K–12 education must align with standards in order to be adopted by schools and teachers and to be integrated into existing curricula.

A Range of Standards: When creating programs and/or materials for a national audience, the National Science Education Standards [1], developed by the National Research Council (NRC) are often matched to program content. Likewise, the Benchmarks for Science Literacy [2] created by the American Association for the Advancement of Science (AAAS) are commonly used in curriculum development. However, the National Science Education Content Standards and Benchmarks tend to be broad, and do not necessarily reflect requirements at the state and local level. In their 2006 survey of K–8 core curriculum astronomy standards for 48 states and the District of Columbia, Palen and Proctor [3] note that, based on their analysis, "Curriculum developers are wise in using the NRC standards as a jumping-off point for curriculum development." However, they also caution that with regard to astronomy content standards "none of the topics is covered in all states, and only seven are covered in more than 80% of states."

State content standards vary widely, but in many states, including Texas, serve as the requirements for school accountability ratings based on assessment through state-administered exams. Local district curricula, sometimes referred to as scope and sequence, can be substantially more detailed than state standards. In some school districts, local requirements limit teachers to specific lessons on given days, rather than simply requiring that specific content be taught during an academic year.

The Palen and Proctor study dealt only with astronomy and did not address high school, where Earth and space science are often neglected entirely by state standards, or occur in courses that will not be encountered by a majority of students. The challenge of integrating space science content into K–12 formal education is therefore greater than the K–8 NRC standards to state standards correlations in astronomy would suggest. Identifying fundamental concepts that do meet the teaching needs of today's schools, not just in space science and Earth science, but in the "core" curriculum areas of physics, chemistry, and biology will aid the exciting cutting edge work of the space science community into making the transition into K-12 classrooms.

Engage and Elaborate: A widely adopted framework for curriculum design is the 5 E model [4]. Each "E" stands for phase (or component) of a lesson plan intended for student centered learning.

1. Engagement
2. Exploration
3. Explanation
4. Elaboration
5. Evaluation

Most space science research, including NASA missions, is not obviously tied to fundamental concepts in science standards. However, active space exploration is an excellent opportunity to tap into excitement so frequently inherent in the topic. As such, the education programs designed for these missions can be exceptional opportunities to "engage" students in the learning of fundamental concepts in the standards, as well as to fulfill NASA's vision to "Inspire the next generation of explorers as only NASA can." Likewise, while Exploration and Explanation can focus on the building of fundamental conceptual understanding, the Elaboration phase is another opportunity to bring the excitement of space science research into classrooms.

Depending upon the specific needs of a teacher and his or her students, and the time available, the Evaluation phase of a 5 E lesson may also lend itself to including space science content through project based assessments. Bloom's Revised Taxonomy, as presented by Anderson and Krathwhol [5], orders knowledge (ranging from factual at the lowest level to metacognitive at the highest) and the procedure used to learn (remember, understand, apply, analyze, evaluate, and create). Project-based assessments, sometimes involving actual data as in the case of the Arizona Mars Education Program's *Mars Student Imaging Project* [6] can provide opportunities for students to achieve and demonstrate higher-order learning.

CINDI's Approach: The Coupled Ion Neutral Dynamics Investigation (CINDI) [7] is a UT Dallas built and NASA-funded mission of opportunity launched last April aboard the U.S. Air force Communication/Navigation Forecast Outage System (C/NOFS). Unlike Mars missions, CINDI is not easily engaging to students or the public. As a NASA-funded mission, an Education/ Public Outreach program is required. For a terrestrial ionospheric explorer that returns no images, an additional challenge of our E/PO program has been how to make the science of CINDI understandable. With no easy "hook" and with a partnership between the project science team and the UT Dallas Department of Science/Mathematics Education, we began with the assumption that our focus would be on the formal education for which we had the expertise. With that assumption came our first major challenge.

Challenge 1: How is CINDI relevant to K–12 Education? Both the NRC standards [1] and the Texas Essential Knowledge and Skills [8] played a critical role in our initial selected topics. However, the difference between national standards and those of Texas and several other states also were important in our selection of target grade levels. We initially focused on middle school (grades 6-8) rather than high school because of the inclusion of Earth and space science content in those grade levels. Our "engagement" uses questions that middle school students typically find interesting, such as how can a satellite be both in Earth's atmosphere and in space?

We are now in the process of completing the high school component of our CINDI E/PO program, in partnership with high school teachers. Our focus is using the science of CINDI to teach fundamental physics concepts such as light energy absorption by atoms and molecules (in the context of the Earth's atmosphere), forces and collisions (with ions and neutrals) and electricity and magnetism (in the context of instrument design and space weather). Our paper rocket design challenge from the middle school materials has been easily adapted for use to meet NRC standards and state standards for high school physics. In addition, our new materials for high school physics are being created with the 5 E model.

Challenge 2: The need for high quality professional development. An important and often overlooked [9] component of the National Science Education Standards are the Standards for Professional Development for Teachers of Science [1]. According to the NRC standards the "current reform effort requires a substantive change in how science is taught. An equally substantive change is needed in professional development practices."

As is standard practice for NASA-supported E/PO programs, the CINDI program provides workshops and short courses at local, state, and national teacher conferences. However, through our partnerships with the Science/Mathematics Education Program at UT Dallas we are also able to embed CINDI E/PO professional development within coursework for inservice teachers seeking and in workshops for our ongoing UT Dallas Regional Collaborative for Excellence in Science Teaching. These programs provide opportunities to align CINDI professional development activities closely with the NRC standards, and to make our conference workshops as effective as the limited time available permits [10].

Challenge 3: Making the science of CINDI understandable. Regardless of how well we have met the first two challenges, meeting the third has been absolutely essential to the success of the CINDI E/PO program. Our initial approach was to create a "comic book" highlighting the fictional adventures of an android girl named Cindi to introduce both the science of CINDI and the relevance of the mission to everyday lives of people here on Earth. The comic book also serves as a springboard for some of the high school lessons, and is downloadable in English and Spanish at cindispace.utdallas.edu/education/.

Real data presented in a meaningful context can make science both more understandable and more relevant for students. Following the launch of C/NOFS, Dr. Marc Hairston, CINDI science team member and E/PO Co-Lead has created modules showing real CINDI data along the orbital track above the rotating Earth using Google Earth™. Our future plans include providing students with data models to allow them to create similar data visualizations using Google Earth software.

Conclusions: Space science educational materials can make the transition to K–12 classrooms in meaningful ways. The CINDI E/PO program had challenges above and beyond those faced by many NASA E/PO programs. Our standards-based approach, however, has made CINDI made us successful in reaching our target audience: K–12 teachers and their students.

References: [1] NRC (1996) [2] AAAS (1993) [3] Palin S. and Proctor A. (2006) *AER*, 5, 23-35. [4] Bybee, et al. (2006), The BSCS 5E Instructional Model [5] Anderson L.W. and Krarthwohl D.R. (Eds) (2001) A Taxonomy for Learning, Teaching, and Assessing. [6] http://marsed.asu.edu/activities.php
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